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A PROCEDURE FOR EVALUATING SUBPOTABLE WATER REUSE POTENTIAL AT --ETC(U)
NOV 81 J T BANDY, M MESSENGER, E D SMITH

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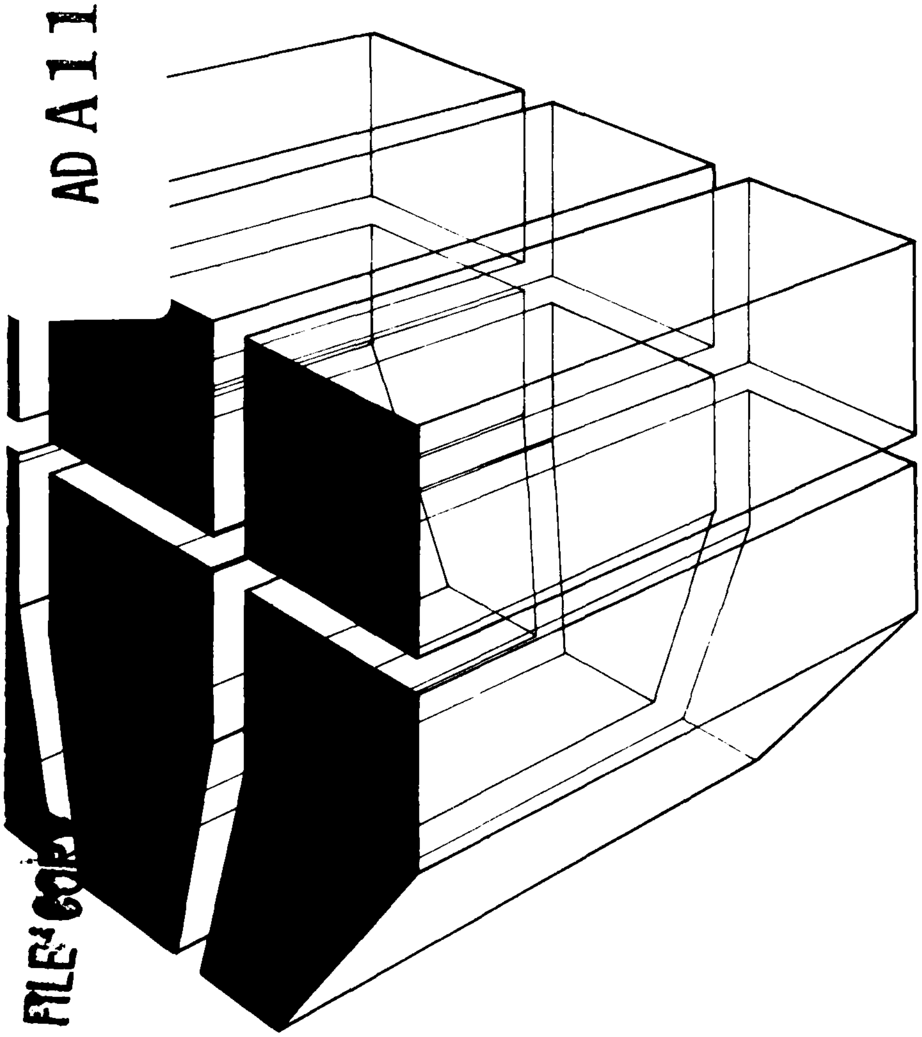
November 1981

A PROCEDURE FOR EVALUATING SUBPOTABLE WATER REUSE POTENTIAL AT ARMY FIXED FACILITIES



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The amendments to the Clean Water Act of 1977 require Army installations to consider wastewater reuse when planning new water or wastewater treatment works. This has created a need for a method that can be used (1) to assess quickly the opportunities for reuse at Army fixed facilities, and (2) to identify the most cost-effective reuse option available. To address this need, U.S. Army Construction Engineering Research Laboratory (CERL) researchers have developed the Wastewater Reuse component of the Pollution Abatement Management

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Systems (PAMS). This will help the Army Facilities Engineers, major commands, and Environmental Offices meet Federal environmental requirements by allowing a quick, accurate assessment of reuse potential, and providing a basis for economic comparison of reuse systems.

FOREWORD

This study was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL) for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A762720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task B, "Pollution Control Technology"; Work Unit 008, "Pollution Abatement Management System." The QCR number is 3.01.004. LTC D. Gilson, DAEN-ZCE, is the OCE Technical Monitor.

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COL L. J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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CONTENTS

	DD FORM 1473	1
	FOREWORD	3
	LIST OF TABLES AND FIGURES	5
1	INTRODUCTION..	9
	Background	
	Objective	
	Approach	
	Scope	
	Mode of Technology Transfer	
	Use of the Model	
2	STAGE 1 -- ASSESSMENT OF REUSE POTENTIAL AND FEASIBILITY............	11
	Part 1: General Information About the Installation	
	Part 2: Information About Major Activities	
3	STAGE 2: CASCADE REUSE NETWORKS.....................................	24
4	STAGE 2: PRELIMINARY COST ESTIMATES.................................	33
	Piping Costs	
	Storage	
	Treatment	
	Pumping	
	Total Costs	
5	STAGE 3: WASTEWATER SURVEYS...	41
6	THE COMPUTER SYSTEM...	42
7	CONCLUSION..	44
	REFERENCES	45
	APPENDIX A: White Sands Missile Range Field Test	47
	APPENDIX B: Water and Effluent Quality	73
	DISTRIBUTION	

TABLES

Number		Page
1	Army Activities With Greatest Potential as Sources of Reclaimed Water	23
2	Army Activities With Greatest Potential as Users of Reclaimed Water	23
3	Army Activities With Greatest Potential for Internal Recycling	23
4	Reuse System Sample Water Balance	32
A1	Chemical Analyses of Composite Samples of Post Water Supply	50
A2	Tolerable Water Quality According to Various References	58
A3	Costs of the Reuse Network	67
A4	Sewage Treatment Plant Influent	69
A5	Sewage Treatment Plant Effluent	70
A6	Photo Lab Data Comparison	71
B1	Tolerable Water Supply Quality -- Aircraft Wash Racks	74
B2	Typical Effluent Quality -- Aircraft Wash Racks	74
B3	Tolerable Water Supply Quality -- Air Pollution Wet Scrubbers	75
B4	Air Pollution Wet Scrubbers -- Typical Effluent Quality	75
B5	Base Housing Water Supply Quality	76
B6	Typical Base Housing Sewage	76
B7	Low Pressure Boilers -- Tolerable Water Supply Quality	77
B8	Low Pressure Boilers -- Typical Effluent Quality	78
B9	Cooling Water (Recirculating Systems) -- Tolerable Water Supply Quality (Also Dynamometers)	79

TABLES (Cont'd)

Number		Page
B10	Cooling Waters (Once-Through) -- Tolerable Water Quality (Also Dynamometers)	80
B11	Typical Effluent Quality -- Cooling Tower Blowdown (Also Dynamometers)	81
B12	Fire Protection/Spill Washdown Reservoirs -- Tolerable Water Supply Quality	82
B13	Hospitals -- Typical Effluent Quality	82
B14	Irrigation -- Tolerable Water Supply Quality	83
B15	Laundries -- Tolerable Water Quality	84
B16	Industrial Laundries -- Typical Effluent Quality	85
B17	Laundromat -- Effluent Quality	86
B18	Metal Cleaning -- Typical Effluent Quality	86
B19	Metal Electroplating and Finishing Rinse Waters -- Tolerable Water Supply Quality, Also Metal Cleaning	87
B20	Paint Booth Water Walls -- Tolerable Water Supply Quality	87
B21	Paint Booth Water Walls -- Typical Effluent Quality	88
B22	Photographic Laboratories -- Tolerable Water Supply Quality	88
B23	Photographic Laboratories -- Typical Effluent Quality	89
B24	Recreational Lakes (Limited Body Contact) -- Tolerable Water Supply Quality	90
B25	Steam Cleaning -- Typical Effluent Quality	91
B26	Vehicle Wash Racks -- Tolerable Water Supply Quality Using Sewage Treatment Plant Effluent	91
B27	Vehicle Wash Racks -- Tolerable Water Supply Quality Using Internally Recycled Water	91
B28	Vehicle Wash Racks -- Typical Effluent Quality	92

TABLES (Cont'd)

Number		Page
B29	Summary of Tolerable Water Supply Quality and Typical Effluent Wastewater Quality	93
B30	Final Lagoon Effluent Quality at Lake City Ammunition Plant and Its Possible Uses	97

FIGURES

1	Basic Types of Reuse Schemes	25
2	Reuse of Reclaimed Sewage Treatment Plant Effluent	26
3	Direct Cascade Reuse of Reclaimed Water	27
4	Cascade Reuse With Pretreatment	28
5	Internal Treatment and Recycling	28
6	Sample Reuse Network Diagram -- Simple Scheme	29
7	Sample Reuse Network Diagram -- Complex Scheme	30
8	Sample Water Balance Diagram for Conceptual Reuse Systems Showing Flow Rates (Cubic Meters, Maximum and Minimum), Requirements for Storage and Additional Fresh Water	31
9	Raw Sewage Pumping (Constant Speed)	37
10	Raw Sewage Pumping (Variable Speed, Curve 1)	38
11	Raw Sewage Pumping (Variable Speed, Curve 2)	39
12	Curve for Estimating Maintenance Hours	40
A1	Cross Section Through Well Field	48
A2	Monthly and Yearly Pumpage in the Post Headquarters Well Field	51
A3	WSMR Facilities	52
A4	WSMR Wastewater Treatment Plant	53
A5	Comparison of Mean/Average Daily Flows	55
A6	Hourly kVA Demand	57

FIGURES (Cont'd)

Number		Page
A7	Schematic of Reuse Network	63
A8	Total Head Developed by Pumping System	66
A9	Average Flow	72

A PROCEDURE FOR EVALUATING SUBPOTABLE WATER REUSE POTENTIAL AT ARMY FIXED FACILITIES

1 INTRODUCTION

Background

The Department of the Army (DA) has many installations in regions where sources of inexpensive, good quality water are limited. In some areas of the western and southwestern United States, surface water is scarce and groundwater is either extremely high in dissolved solids, or so deep underground that pumping is costly. Wastewater reuse can benefit installations by reducing their requirements for potable water. In certain situations, reuse of wastewater can prove an economical solution to both water supply and wastewater disposal problems.

Army Regulation (AR) 200-1 and amendments to the Clean Water Act of 1977 require Army installations to consider wastewater reuse when new water or wastewater treatment works are planned.[1]

A model -- a system of manual and automated procedures -- is needed to help Army planners choose installations where wastewater reuse would be most economical and beneficial, and to identify which of the many possible reuse networks would be most cost-effective.

Such a model has been developed by the U.S. Army Construction Engineering Research Laboratory (CERL) as a component of the Water Pollution Abatement Subsystem (WPAS) of the Pollution Abatement Management System (PAMS).[2]

Objective

The objective of this study was to develop a wastewater reuse model which will allow the Army (1) to assess the potential for wastewater reuse at fixed facilities, and (2) to identify the most cost-effective reuse networks which can be implemented at an installation.

Approach

1. A protocol was developed to quickly assess an installation's potential for wastewater reuse in the course of a 1-day site visit (Chapter 2).

2. Guidelines for developing networks that cascade water among an installation's water-using activities were formulated (Chapter 3).

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[1] Environmental Protection and Enhancement, Army Regulation (AR) 200-1 (Headquarters [HQ], Department of the Army [DA], 20 January 1980).

[2] R. D. Webster, E. D. Smith, and V. Kothandaraman, Pollution Abatement Management System -- Concept Definition, Technical Report N-42/ADA055565 (U.S. Army Construction Engineering Research Laboratory [CERL], May 1978).

3. A method for making rough cost estimates for the proposed networks was devised (Chapter 4).

4. A computer system that validates and compares the cost of the wastewater reuse networks proposed for an installation was developed (Chapter 6).

5. The reuse model was field tested at White Sands Missile Range (WSMR) in conjunction with the Army Environmental Hygiene Agency (AEHA). (An account of the WSMR field test is presented in Appendix A.)

Scope

The reuse model is applicable to installations that produce wastewater similar to typical domestic sewage. It is not concerned with heavily industrial operations such as munitions manufacture.

Mode of Technology Transfer

The information in this report will be used to document AR 18-1 requirements. This information will specifically form a basis for the General Functional System Requirements and for development of the Project Master Plan for PAMS. In addition, this information will serve as a basis for an Engineer Technical Note (ETN), which will be prepared after field testing of the approach.

Use of the Model

To use the model, the installation must first identify facilities that have potential for subpotable water reuse (Stage 1). Then schematic diagrams of networks that cascade water among an installation's water-using activities are developed; the costs of the networks are estimated so those that are not economical can be eliminated (Stage 2). Finally, actual water quality and flow data must be gathered on post (Stage 3) for input to a computer system that evaluates the feasibility of each wastewater reuse system being considered.

2 STAGE 1 -- ASSESSMENT OF REUSE POTENTIAL AND FEASIBILITY

In Stage 1 of the wastewater reuse model, efficient, straightforward methods are used to identify facilities that have potential for subpotable water reuse. The techniques have been designed so that a knowledgeable person can complete them during a 1- to 2-day site visit.

Completion of Stage 1 requires a sound general knowledge of five major areas of the installation: water supply, wastewater treatment/disposal, institutional aspects of the water and wastewater systems, environmental factors, and energy. The evaluators responsible for completing Stage 1 need not be sanitary engineers; however, they should be familiar with Army installations, should be completely briefed on the purpose of the Stage 1 model, and should have enough technical background to discuss water supply systems, wastewater treatment, and Army activities.

Most important, at each post the evaluators must locate key persons who have or know where to obtain the information needed for Stage 1. The Chief of Utilities or another member of the Facilities Engineering Office can furnish much of the information. The Master Planning Office will know about future events that may change the water/wastewater scenario or the activities of the installation.

Part 1: General Information About the Installation

Answers to the following questions must be obtained as the first step in completing Stage 1:

1. Water Supply

A key to wastewater reuse potential is the availability and cost of the installation water supply, both now and in the future. Water shortages, potential water supply problems, and high water usage are all factors that make reuse attractive.

a. Is the installation water supply available from a reliable source for the next 20 years?

(1) What is the source?

(2) Where is it?

Remarks: a negative response indicates possible long-range supply problems, making reuse advantageous.

b. Is there possible significant depletion of the water supply within the next 10 years?

(1) If so, what is the cause?

(2) What alternative sources of supply exist?

(3) What planning has been done to meet this contingency?

Remarks: a positive response means there will be future planning and possible design of new water supply facilities -- a good time to evaluate reuse.

c. Is there a problem anticipated with the water supply within 5 years?

(1) What is the problem?

(2) What are the possible solutions?

Remarks: positive response -- high rating for reuse as evaluation and planning for new or additional water supplies should include reuse possibilities.

d. Is there a foreseeable event that could markedly increase water costs in the next 10 years?

(1) What?

(2) How much?

Remarks: although costs may be reasonable now, many areas are realizing increased costs as water sources are depleted and quality degrades. Future cost increases benefit reuse economics.

e. List average water use in million gallons per day (mgd) for each month of the last year (see water treatment plant [WTP] records).

f. Check type of testing done on influent and effluent of WTP. (This information is available from the plant superintendent.)

	Influent	Effluent
Total dissolved solids (TDS)		
Suspended solids (SS)		
Coliforms		
Biochemical oxygen demand (BOD)		
Total organic carbon (TOC)		
Chemical oxygen demand (COD)		
Nitrogen		
Other (specify)		

g. What is the present cost of water procurement and treatment per 1000 gal (3790 L)? (This information is available on FORSCOM Form 243-2-R, 1 July 1977.)

Remarks: high water costs are a driving force for reuse as the economics of reuse become more attractive.

h. Is expansion or upgrading of the water supply/treatment system planned in the next 10 years?

Remarks: reuse can provide savings in reduced plant capacity. Planning should include reuse feasibility.

i. What is the effective population on the installation? Is this going to increase or decrease greatly in the future?

j. What changes in activities are planned for the next 10 years?

(1) Are more industrial activities planned?

(2) What will be the water use requirements of planned changes?

2. *Wastewater*

Wastewater management is an important consideration for reuse: treatment facilities, effluent quality, discharge requirements, costs, and volumes are important factors. In general, installations with high-volume treatment facilities discharging high-quality effluent have good reuse potential; this is also true of installations at the other extreme -- with outdated or overloaded treatment facilities that are unable to meet discharge requirements.

a. Does the installation treat wastewater for direct discharge to surface water or land?

(1) What is the name of the receiving body of water?

(2) If land discharge, describe system.

(3) If not, how and where is sewage discharged?

Remarks: direct discharging installations have more reuse potential because of the problems associated with meeting increasingly stringent discharge requirements. Reuse is one answer for reducing plant loadings, or for eliminating discharges altogether.

b. Does the installation treatment plant presently meet discharge requirements?

(1) Describe noncompliance (sewage treatment plant [STP] records).

(2) Provide National Pollutant Discharge Elimination System (NPDES) permit information.

Remarks: a negative response indicates a wastewater management problem for which reuse may be part of the solution.

c. Are there plans to upgrade or add to the existing treatment facilities within the next 5 years?

Remarks: a positive response indicates planning, design, and construction of new facilities. Reuse could have positive impact, or could conceivably alleviate the problem so that new facilities would not be necessary.

d. Are there plans to hook into a regional or municipal sewage system?

e. Are there plans to accept wastewater from surrounding communities for treatment?

f. Draw a simple process train for the installation STP; include design capacity.

g. List average flow in mgd for each month of the last year (STP records).

Remarks: as plants near design capacity, decisions about expansion or reuse have to be made. Problems with overloading may be solved by reuse. Economies of scale favor reuse at installations with large volumes of wastewater.

h. Fill in the minimum and maximum monthly averages for the parameters listed below for the past year. (This information is available on the form filled out for the NPDES discharge monitoring report: OMB #158-r00.)

	Minimum and Month of Occurrence	Maximum and Month of Occurrence
mg/L BOD		
mg/L Total N		
mg/L SS		

Remarks: good quality effluent is a bonus for reuse because little extra treatment is required, making it more economical.

i. Does an industrial wastewater treatment plant (IWTP) exist on post?

(1) Does it meet discharge requirements?

(2) What quality is plant effluent with respect to COD?

(3) Are discharge limits set for specific contaminants? Which ones?

Remarks: industrial waste treatment plants with specific contaminant limits are likely to have a higher quality effluent (better for reuse). They may also have problems meeting these discharge standards, in which case reuse may help.

(4) What is average monthly flowrate in mgd for the last year for the IWTP?

(5) Has the IWTP effluent ever caused problems at STP?

(6) List average monthly IWTP flows for the past year.

j. If municipal or regional sewer system is used,

(1) What is the discharge fee and rate structure?

(2) Are future changes likely that would markedly increase the discharge fee?

Remarks: high discharge fees have a positive effect on reuse economics.

2. *Institutional Factors*

a. Do any long-term agreements for water purchase prohibit the installation from reducing water use?

Remarks: constraints on the ability to reduce water usage are obviously detrimental to reuse programs.

b. Do any water laws or agreements prohibit the installation from reducing the volume of effluent discharged?

Remarks: constraints on the ability to reduce wastewater discharge volumes are detrimental to reuse programs.

c. Is any type of wastewater reuse or water recycle occurring on post?

(1) What percentage of the wastewater is being reused? Where? How?

(2) What percentage of the water is being recycled? Where?

Remarks: installations already reusing a portion of their wastewater are obvious candidates for a more comprehensive reuse plan.

d. Are key installation personnel interested in using reclaimed water? Name point of contact (POC).

e. Are key installation personnel opposed to using reclaimed water? Name POC.

Remarks: the attitudes of key personnel toward wastewater reuse are prime factors in the success of a program.

4. *Environmental Factor*

Another area of interest is meteorological and hydrogeological data. Because of the value of irrigation as a major sink for reclaimed water, installations in arid or semi-arid areas may have more reuse applications than installations in areas of adequate rainfall. Although not always the case, installations in dry areas tend to have more serious water supply problems than those in more temperate zones.

a. What is the average monthly rainfall on post? (This information can be obtained from the local weather forecaster, a nearby university department of atmospheric sciences, or a meteorological monitoring station.)

b. What is the monthly average reservoir evaporation on the installation?

c. At what average depth is the water table located? (The U.S. Geological Survey [USGS] may be able to supply this information.)

d. Is the aquifer from which the installation draws its supply the sole source available?

(1) What is its estimated life?

(2) Is there a salt water intrusion problem?

(3) Is groundwater recharge being practiced?

e. Are there any natural or artificially filled lakes on installation?

(1) Current use

(2) Acres and depth

(3) Sources of water

(4) Any quality data available?

f. Are any reports available on these topics from USGS, AEHA, or contractor studies?

g. What groundwater protection laws apply to this region?

5. *Energy*

Energy usage is an ever-increasing concern; water supply and disposal systems often use large amounts of electrical energy. If the total head and/or distance over which the water supply must be pumped is great, the potential for reuse increases. If power costs for wastewater treatment and disposal are high, irrigation or another consumptive use before treatment may save power costs by reducing the plant load.

a. Obtain copies of rate calculations for both water and sewage disposal service for as many years past as available.

b. What is the current charge for electricity in cents per kilowatt-hour (kWh)? Describe the rate structure.

c. What is the projected cost of electricity for water and sewage treatment over the next 20 years?

d. Is any electricity produced on post?

(1) What is the cost of production in cents per kWh?

(2) What fuel is used?

e. Are there plans to produce electricity on post?

f. How is the 20 percent reduction in energy use mandated by DA for 1985 going to be achieved?

g. What plans have been made for energy conservation?

Data Analysis

Based on the information obtained, a decision must be made about whether the installation could benefit from wastewater reuse. This requires a great deal of judgment. Several factors contribute to a decision to proceed, but no attempt should be made to use a cookbook formula to reach a conclusion:

1. If the water supply is not available from a reliable, adequate, and inexpensive source currently or in the near future, reuse should be examined further.

2. If additional water treatment works are going to be necessary, reuse may be more economical.

3. A high volume of wastewater and a good quality effluent contribute to the cost-effectiveness of reuse.

4. Noncompliance with NPDES permit requirements may make reuse beneficial if consumptive uses for the wastewater can be found (e.g., irrigation), or if the total volume of wastewater can be reduced to alleviate STP overloading.

However, if the installation is committed by prior agreements or laws to stated volumes of water use and wastewater discharge, reuse may not be possible. If a high percentage of water or wastewater is already being reused, most of the opportunities for reuse may have been exploited.

5. In many places, reclaimed water is used for irrigation, which tends to be a large percentage of total water use in climates experiencing low rainfall or high evaporation. Lakes can serve as sinks or storage areas for reclaimed water and can provide recreation.

6. High power costs for water supply or disposal contribute to the cost effectiveness of reuse.

Part 2: Information About Major Activities

In Part 2, information is sought on the spatial relationships and estimated water use/wastewater discharge of the major activities on post.

To determine spatial relationships, a base map showing elevations and having a scale of at least 1 in. = 500 ft should be obtained. The individual(s) who seemed most knowledgeable about the water systems in Part 1 should be asked to point out the major water-using activities. These locations should be circled and labeled on the map.

High volume is essential to cost-effective reuse networks. Unfortunately, water is rarely metered on Army posts, and accurate estimates of the water use by individual activity are often not available from either the Facility Engineer's (FE's) office or the activities themselves. Every effort should be made to develop accurate usage and discharge estimates as well as daily, weekly, and monthly usage patterns for each activity. If the FE's office cannot provide this information, a point of contact at the activity in question should be found.

Appendix B presents data on tolerable water quality and typical effluent quality for 13 common Army activities.[3] The following information should be obtained on post, if possible; the data in Appendix B should be used only after all avenues of inquiry have been exhausted.

1. Golf course(s)

   a. Number of acres.

   b. Number of acres irrigated.

   c. Is potable water used?

   d. Describe existing irrigation system (automatic, manual, etc.).

   e. During which months is watering necessary?

   f. Is any other source of irrigation water available (such as a lake or quarry) close to the course?

   g. Daily, weekly, monthly usage patterns.

   h. Usage estimates.

2. Large cooling towers (water type) > 50 tons

   a. Number.

   b. Number of tons capacity at each location (refrigeration shop records).

   c. Blowdown rate (gallons/ton/hour).

[3] As the tables indicate, some of the information is from SCS Engineers. For a more detailed explanation of the tables, see Curtis J. Schmidt, Ernest V. Clements III, and Leanne Hammer, Subpotable Water Reuse at Army Fixed Installations: A Systems Approach, Volume I, ADA075159 (SCS Engineers, supported by U.S. Army Medical Research and Development Command, August 1979).

d. Evaporation rate (gallons/ton/hour).

e. Chemicals used.

f. Months of usage.

3. Landscape, athletic fields, parade grounds

a. Acreage presently irrigated.

b. Additional acreage that could be irrigated if reclaimed water were available.

c. Daily, weekly, monthly usage patterns.

d. Usage estimates.

4. Vehicle and aircraft washracks

a. Number of washracks.

b. Number of vehicles.

c. Number of washings/month/vehicle.

d. Daily, weekly, monthly usage patterns.

e. Usage estimates.

5. Steam cleaners

a. Number.

b. Hours per week in use.

c. Daily, weekly, monthly usage patterns.

d. Usage estimates.

6. Metal plating and finishing

a. Daily, weekly, monthly usage patterns.

b. Usage estimates.

c. Pretreatment provided before discharge.

7. Boilers

a. Btu capacity.

b. Months in use.

c. Blowdown rate.

8. Autoclaves

   a. Number and size.

   b. Hours per week usage.

   c. Daily, weekly, monthly usage patterns.

   d. Usage estimates.

9. Paint booth water walls

   a. Number.

   b. Daily, weekly, monthly usage patterns.

   c. Usage estimates.

10. Air pollution wet scrubbers

   a. Type: spray, towers, cyclones, venturis, packed or floating beds.

   b. Daily, weekly, monthly usage patterns.

   c. Usage estimates.

11. Dynamometers

   a. Number.

   b. Daily, weekly, monthly usage patterns.

   c. Usage estimates.

12. Industrial laundries

   a. Number and capacity of washers.

   b. Daily, weekly, monthly usage patterns.

   c. Usage estimates.

13. Photo processing facility

   a. Daily, weekly, monthly usage patterns.

   b. Usage estimates.

   c. Pretreatment provided.

14. Civilian water users close to post

   a. Golf course.

b. Power plant.

c. Agriculture.

d. Others.

Remarks: large civilian water users near the installation can offer a sink for reclaimed water if the quality is acceptable and the economics of transport are feasible.

15. Describe reuse projects planned or existing in surrounding communities.

16. Other installation water-using activities

a. Description.

b. Daily, weekly, monthly usage patterns.

c. Usage estimates.

The decision to be made at this point, based on the data obtained above, is whether reuse is economically feasible.

Rough daily water balances for the installation as a whole should be calculated to reflect both summer and winter usage patterns as well as any other unique seasonal patterns that may exist.

High volume of water usage is essential both for potential sources and users of reclaimed water. A good source produces enough wastewater for reuse to be economical due to freshwater savings and/or wastewater discharge reduction. Good potential users of reclaimed water take significant volumes on a regular basis -- for example, industrial cooling towers. Irrigation can use tremendous volumes of reclaimed water; however, good estimates of the water volume for irrigation are rarely available on post.

A rough estimate of irrigation usage can be obtained by looking at the average daily water production for each month during the irrigation season and subtracting from each the volume of wastewater treated at the STP that month plus the volume of water for other consumptive purposes. Other consumptive uses frequently encountered include evaporative air conditioning, aircraft and vehicle washracks that drain to the storm sewers, and steam production.

Reliable flow is another important attribute of good sources and (to a lesser extent) good users of reclaimed water. The source flow should be predictable so that storage needs can be determined and a reliable supply provided to user activities. User demands should be consistent so that accurate estimates of costs and savings can be determined.

Finally, a good source of reclaimed water should not be so highly contaminated that prohibitively expensive treatment would be needed before reuse.

Some industrial wastewaters -- e.g., steam cleaning and metal cleaning wastes -- require extensive waste treatment before reuse to remove or neutralize such diverse contaminants as oils, grease, cyanides, phenols, heavy metals, phosphates, acids, and caustics, and therefore have very low reuse potential. However, other industrial effluents -- e.g., some plating shop rinse waters and cooling system blowdowns -- meet the above criteria and are good candidates for reuse.

Sanitary and domestic-type wastewaters from housing, community, protective, administrative/institutional, and commercial activities also have excellent reuse potential. At most Army posts, these wastewaters are collected by the sanitary sewer system into a single sewage flow which can often be reused after secondary or tertiary treatment in a sewage treatment plant. A post STP which works well improves the economics of reuse considerably. IWTP effluents can also be reused if the treatment is complete and effective. IWTP effluent is advantageous because both bacterial and viral contamination can be very low. However, before these waters can be reused, oils and dissolved metals and salts must often be removed.

The best users of reclaimed water are those that can handle good secondary effluent because it is usually available and not expensive to produce. Activities that can use filtered secondary effluent also have good potential because most secondary plants can be readily upgraded with filtration, although this is more expensive. Activities that require very high water quality (e.g., boilers) are generally poor users because the technology to purify wastewater is too expensive in most cases. Although only nonpotable reuse is considered in this report, bacteria and viruses in the reclaimed water can be a hazard in those activities that include human contact with water sprays and aerosols. Such activities include wash and steam racks, paint water walls, and, to a lesser extent, spray irrigation of golf courses and landscapes. Typical Army activities with the greatest potential as sources of reclaimed water are listed in Table 1, as users of reclaimed water in Table 2, and as users of internal recycle in Table 3.

If promising sources and sinks for reclaimed water are present on post, networks should be developed that route the water from activity to activity. Many small, scattered sources and users make reuse harder to implement economically. However, with very high water-supply or wastewater-treatment costs, or an inadequate or unreliable supply, reuse networks for these unpromising activities also should be drawn and considered, as described in Chapter 3.

Table 1

Army Activities With Greatest Potential as Sources of Reclaimed Water

Industrial	Housing, Community, Protective, Administrative/Institutional, and Commercial*	Wastewater Management
Vehicle wash racks		Sewage treatment plant effluent
Aircraft wash racks		Industrial waste treatment plant Metal plating and finishing effluent Cooling towers Dynamometers Industrial laundries Boilers

*The total sewage flow from these activities should be considered as one wastewater source.

Table 2

Army Activities With Greatest Potential as Users of Reclaimed Water

Community	Commercial	Industrial
Golf course irrigation	Laundry	Cooling towers
Landscape irrigation		Paint booth water walls
Athletic field, playground, park irrigation		Air pollution wet scrubbers
Recreational lakes and ponds		Autoclaves Dynamometers Vehicle wash racks Aircraft wash racks Steam cleaning Ash handling system water Maintenance wash downs

Table 3

Army Activities With Greatest Potential for Internal Recycling

Industrial Activities
Metal plating and finishing
Vehicle wash racks
Aircraft wash racks
Dynamometers
Large industrial autoclaves
Cooling towers
Paint booth water walls
Air pollution wet scrubbers

3 STAGE 2: CASCADE REUSE NETWORKS

The second stage of the model requires 2 days of office work. Conceptual reuse systems are developed for the installation. All the data gathered on activities and spatial relationships are used to develop feasible reuse networks. These networks are essentially schematic diagrams showing the distribution of fresh and reclaimed water throughout the base, as well as the collection, treatment, reuse and disposal of wastewaters.

Several basic types of water reuse are practical for Army installations, depending on the performance of treatment facilities, major industrial or irrigation activities, and other factors (Figure 1).

1. Treated effluent reuse: the direct reuse of secondary or tertiary effluent from an STP or IWTP by an activity -- e.g., irrigation and cooling towers. Figure 2 lists other activities that can use effluent.

2. Direct cascade reuse: the direct reuse, without treatment, of the discharge from one activity as the water supply for another activity. The donor activity usually has a fairly clean discharge, and the user activity can tolerate low quality water. Feasible pairings are shown in Figure 3.

3. Cascade reuse with pretreatment: the same as direct cascade reuse with an intervening treatment step to bring the donor's wastewater up to the recipient's quality requirements. These pairings are generally practical only when simple treatment can do the job (Figure 4).

4. Internal recycling: the reuse of wastewater as new source water for the same activity. For instance, recirculating water can be used in paint shop water walls and air pollution scrubbers. The water can be continuously bled off and made up, or periodically dumped and refilled. Other activities can be altered to internal recycling systems by treating the wastewater and mixing it in with a freshwater supply. Candidate activities are shown in Figure 5.

Some installations may be able to incorporate more than one of the basic reuse systems in a total reuse scheme. The evaluator must compare actual installation activities and existing treatment facilities, and plan possible reuse networks. The most efficient way to lay out these networks is to look first at large sources and users and develop a basic system around them. Smaller users can be added when it appears they would not add significantly to the total cost -- if, for example, they are close to the source, will not require further treatment of the source water before reuse, and will not need excessive amounts of plumbing or storage. The treatment processes required between different activities can be selected by referring to Figures 2 through 5. All feasible networks should be drawn for consideration. This part of the model requires the highest level of engineering judgment to complete. Figure 6 depicts a simple reuse network that involves STP effluent reuse to irrigate a golf course. Figure 7 shows a more complex reuse scheme that includes multiple STP effluent uses, plating wastewater reuse, and internal reuse at a tank washrack.

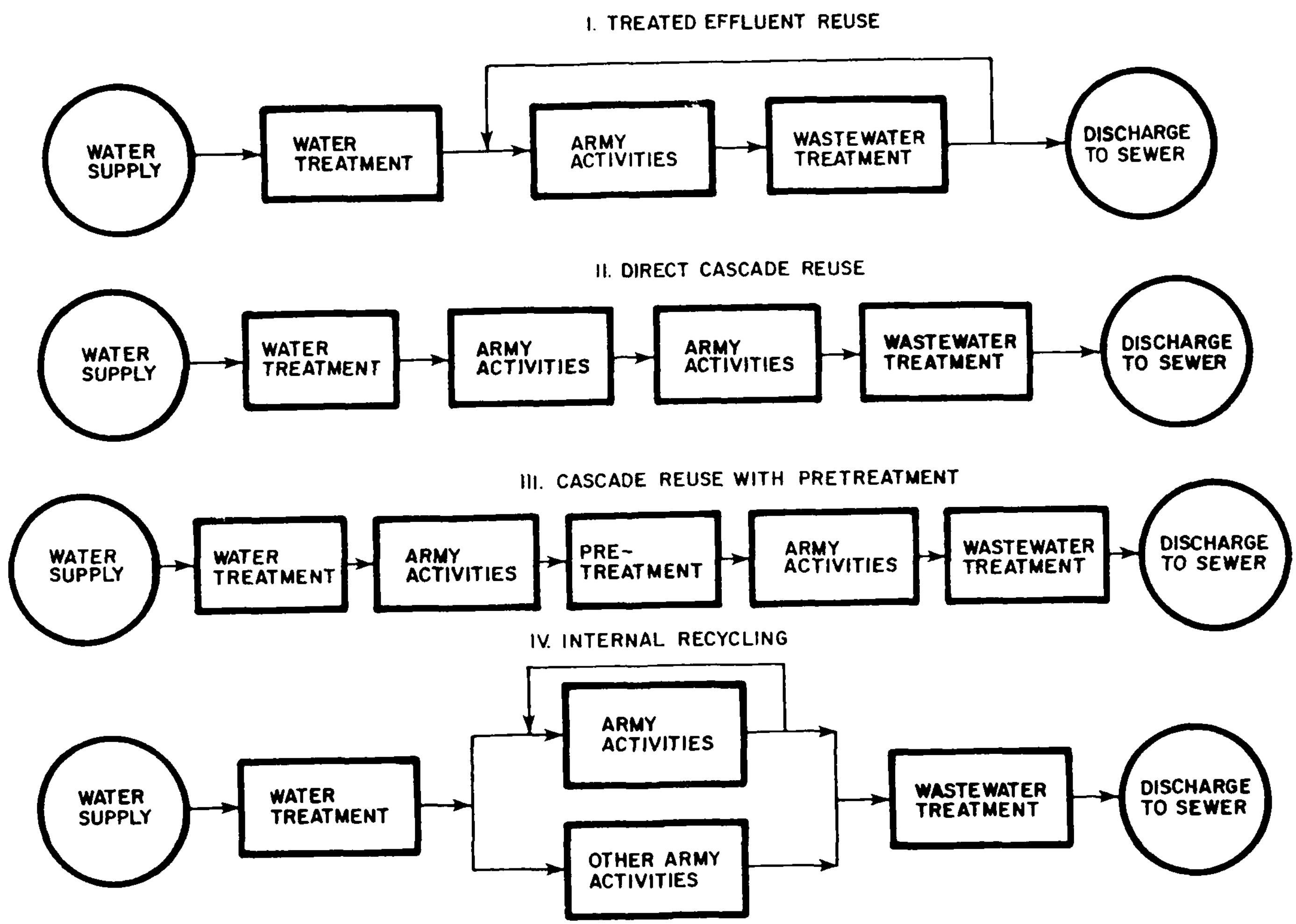


Figure 1. Basic types of reuse schemes.

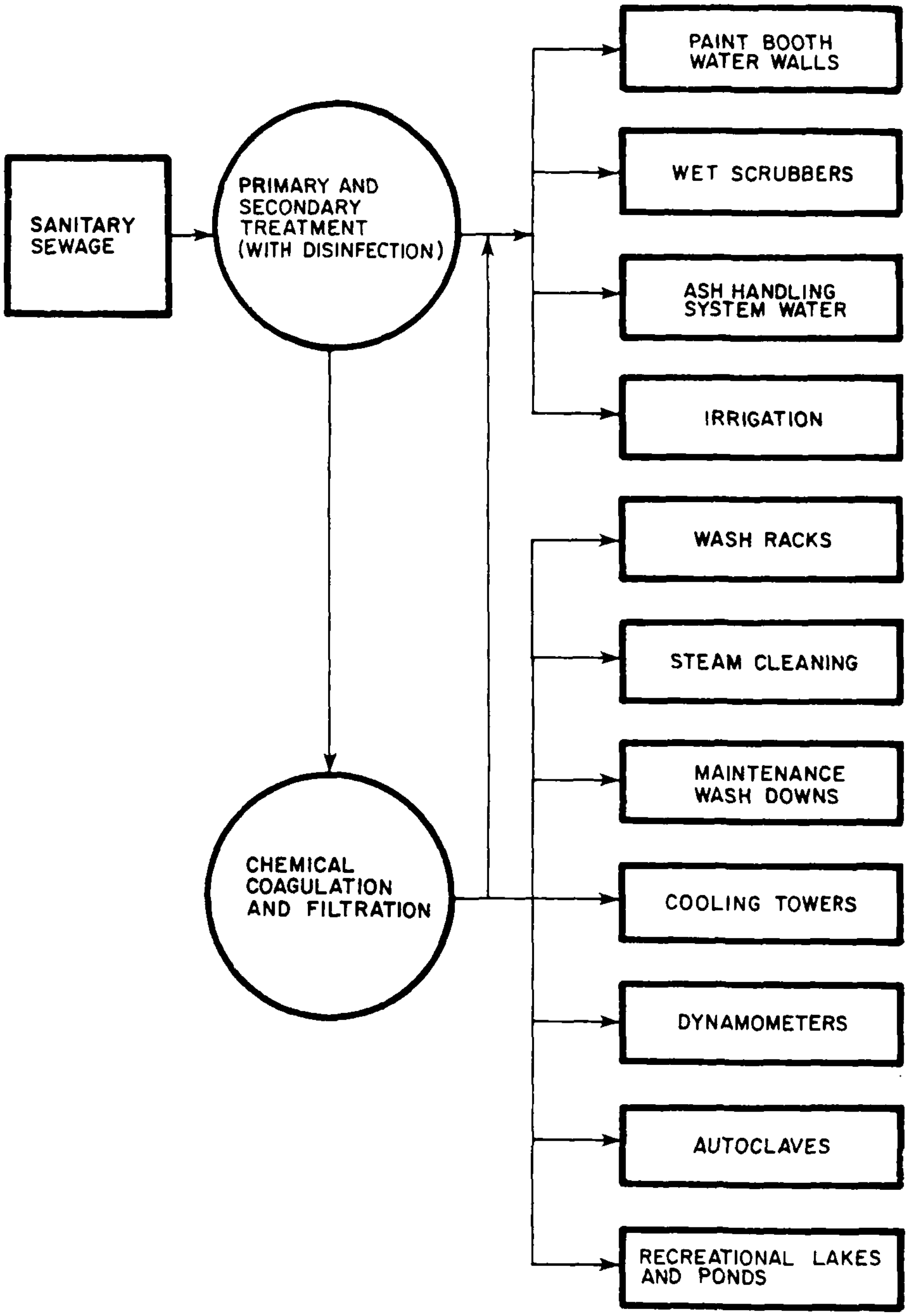


Figure 2. Reuse of reclaimed sewage treatment plant effluent.

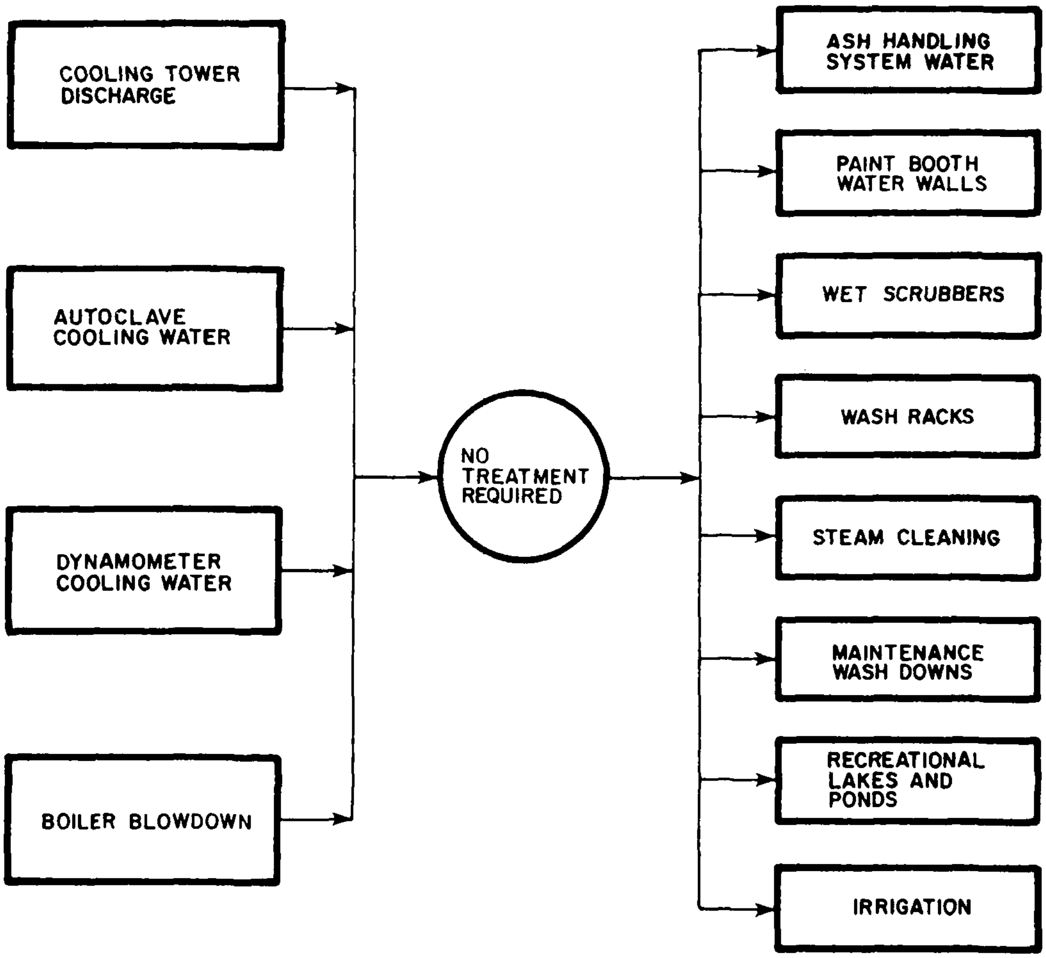


Figure 3. Direct cascade reuse of reclaimed water.

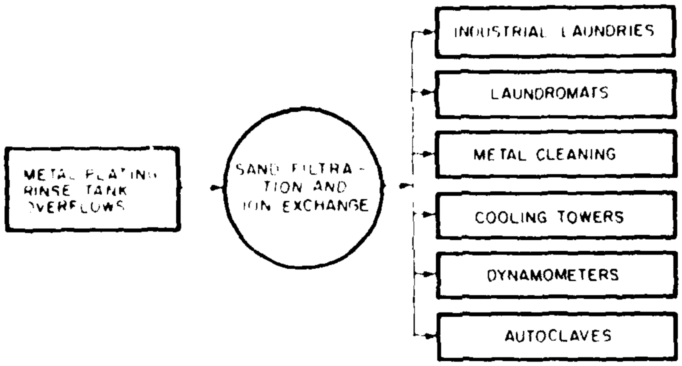


Figure 4. Cascade reuse with pretreatment.

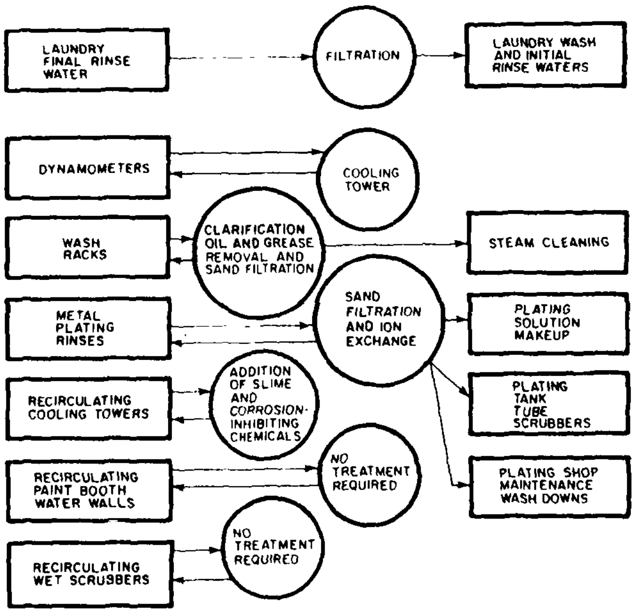


Figure 5. Internal treatment and recycling.

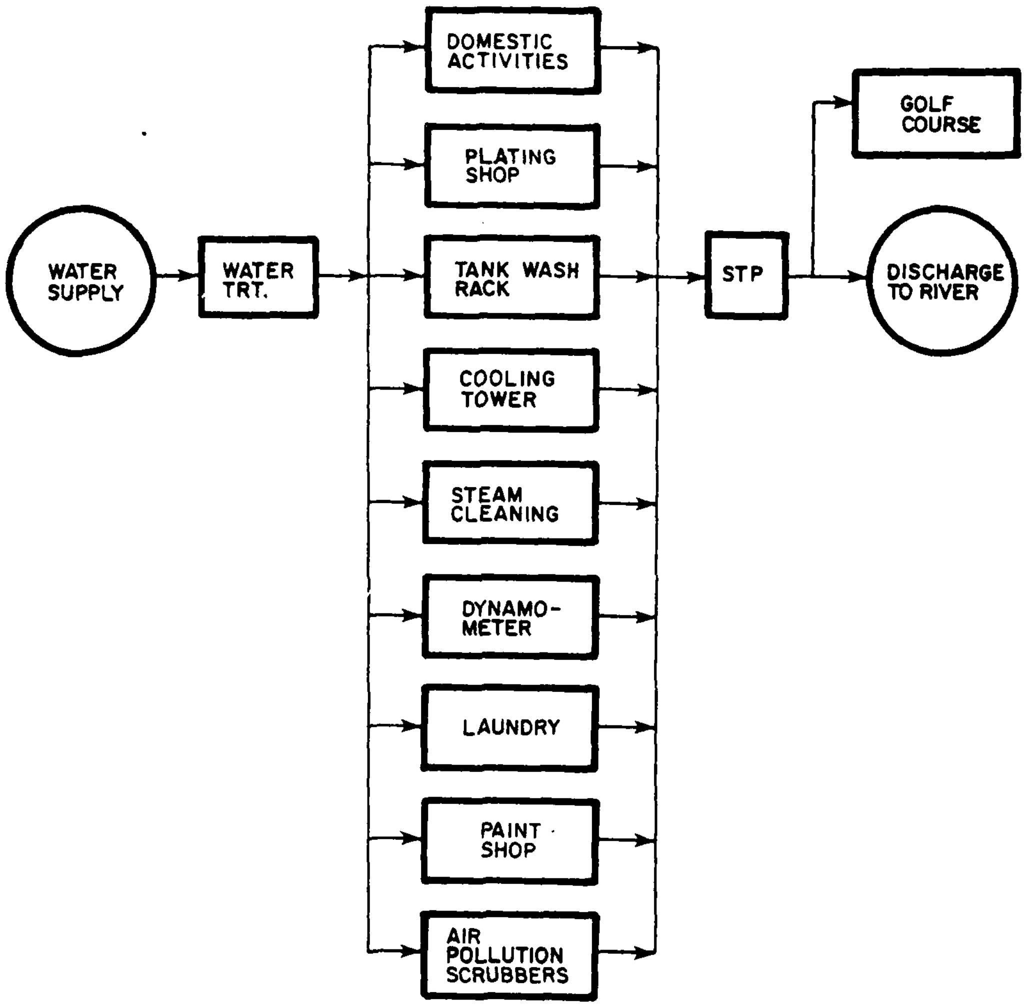


Figure 6. Sample reuse network diagram -- simple scheme.

At this point, a general water balance for each network should be developed to help calculate required storage capacities and ensure that water supply requirements are met.

Where seasonal variations are large, it is often valuable to develop water balances on a monthly as well as a daily basis. It is important to obtain data for maximum and minimum days and months. Such variations may be due to seasonal effects (e.g., irrigation) or changes in staffing levels (training, maneuvers, etc.). Storage requirements will depend on the differences between source and user activities during both minimum and maximum flow. The storage required and the flows encountered can then be transferred to the reuse network diagrams as demonstrated in Figure 8. Table 4 shows a completed sample balance.

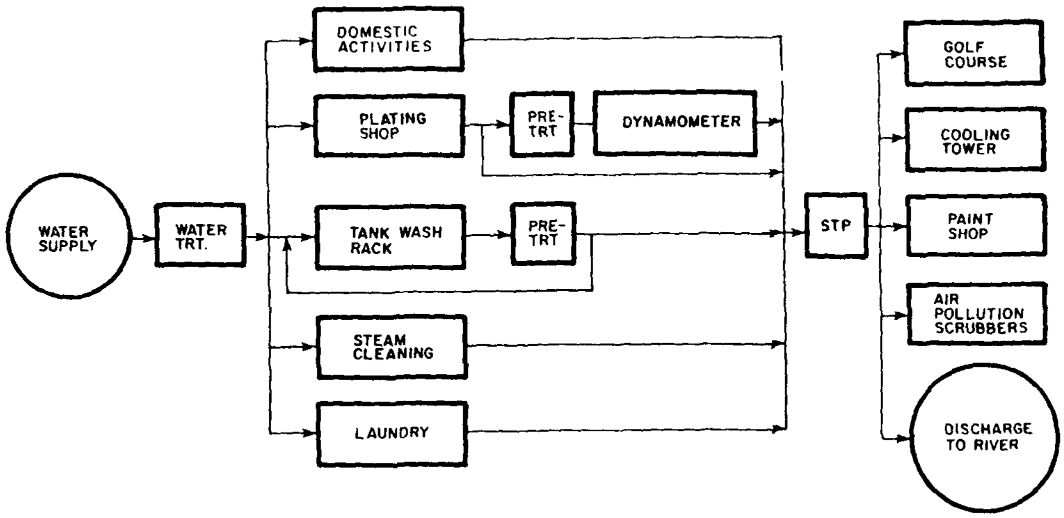


Figure 7. Sample reuse network diagram -- complex scheme.

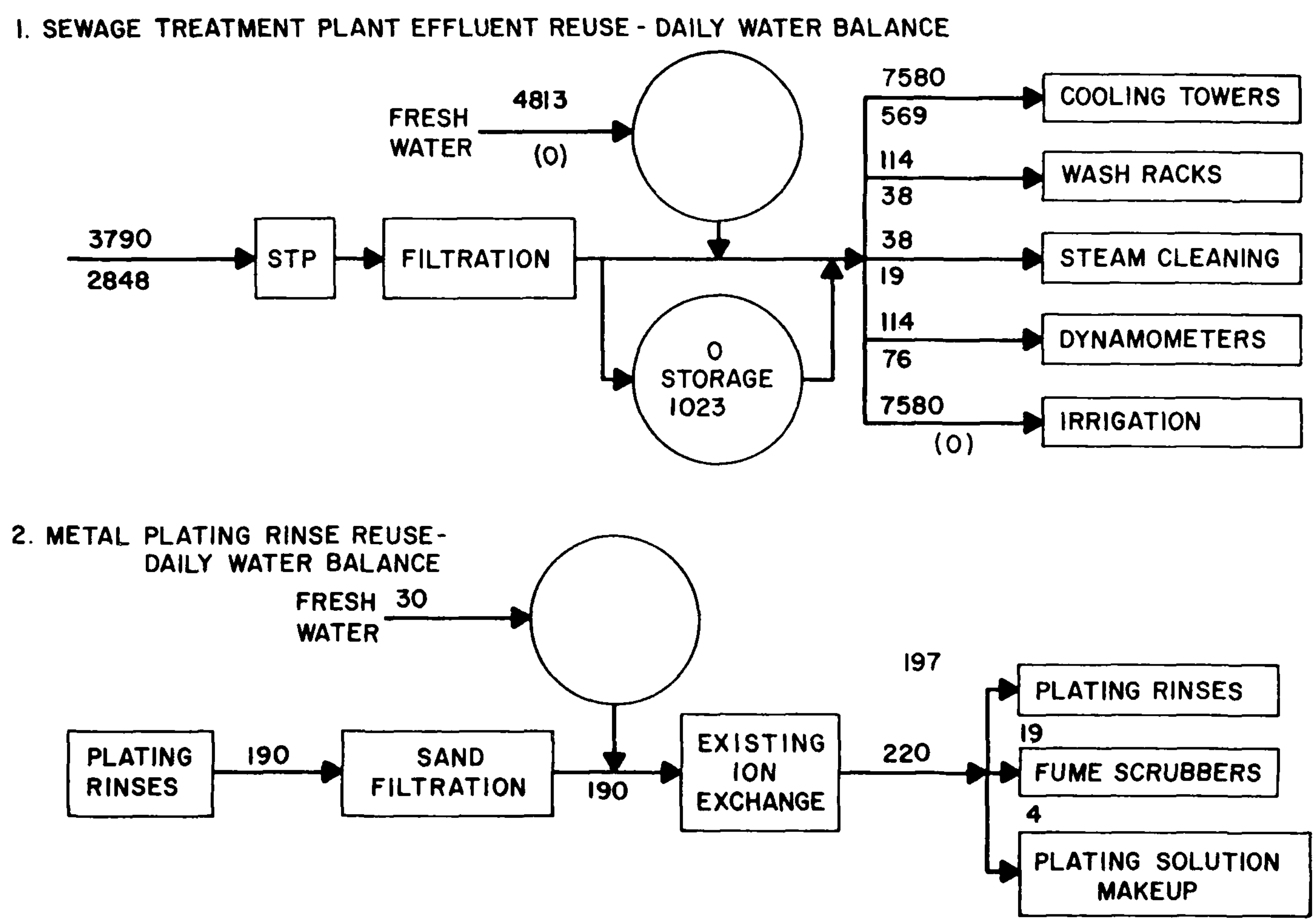


Figure 8. Sample water balance diagram for conceptual reuse systems showing flow rates (cubic meters, maximum and minimum), requirements for storage and additional fresh water.

Table 4

Reuse System Sample Water Balance

Conceptual Reuse System No.	Wastewater Sources			Reclaimed Water Users			
	Source	Flow, gpd (L) or gal/mo (L)				Flow, gpd (L) or gal/mo (L)	
From Figure 8	Activity	Max.	Min.	Treatment Required	User Activities	Max.	Min.
1.	Sewage treatment plant effluent	1,000,000 (3,790,000)	750,000 (2,847,500)	Secondary treatment plus sand filtration	Cooling towers	200,000 (758,000)	150,000 (568,500)
					Wash racks	30,000 (113,700)	10,000 (37,900)
					Steam cleaning	10,000 (37,900)	5,000 (18,950)
					Dynamometers	30,000 (113,700)	20,000 (75,800)
					Golf course and other area irrigation	2,000,000 (7,580,000)	0
2.	Metal plating rinses	50,000 (189,500)	50,000 (189,500)	Sand filtration plus ion* exchange	Metal plating rinses	52,000 (197,080)	52,000 (197,080)
					Plating shop fume scrubbers	5,000 (18,950)	5,000 (18,950)
					Plating solution makeup water	1,000 (3790)	1,000 (3790)

*Already existing.

4 STAGE 2: PRELIMINARY COST ESTIMATES

Evaluating a network using the computer system (Chapter 6) is expensive because actual water quality parameters and flow patterns for each activity's influent and effluent must be determined. This requires that a wastewater survey be done on post. Preliminary cost estimates are needed so that networks that are clearly not cost-effective can be eliminated before the survey.

The amounts and costs of materials, labor, and energy needed to implement a reuse network must be calculated. The first step is to establish, using the water and sewage costs obtained in Stage 1, the water and sewage treatment savings realized by each network (in gallons per year and dollars per year). These potential savings will be compared to the costs of the networks.

Next, both capital and operations and maintenance (O&M) costs must be estimated for each network. The major expenses are those for piping, pumping, storage, and additional treatment.

Piping Costs

The length of pipe needed for each network is obtained by measuring distances between activities on the map and converting to feet. The necessary pipe diameters can be calculated using the relationship

$$\text{Area, sq ft} = \frac{\text{flow, cu ft/sec}}{\text{velocity, ft/sec}}$$

$$\frac{\pi d^2}{4} = \frac{Q\text{, cu ft/sec}}{V\text{, ft/sec}} \qquad \text{[Eq 1]}$$

$$d = \frac{4Q}{\pi v}^{1/2} \text{ feet}$$

where: Q = flow, cu ft/sec
V = velocity, ft/sec
d = pipe diameter, ft.

The maximum flow to be carried should be used to decide the proper size for the pipe. A typical flow velocity of 5 ft/sec can be used for this rough costing.

The appropriate type and diameter of pipe can be quickly costed by referring to the current Means Building Construction Cost Data or Dodge Guide to Public Works and Heavy Construction Costs.[4]

O&M costs on the pipe network are negligible.

[4] Dodge Guide to Public Works and Heavy Construction, Annual Edition No. 12 (McGraw-Hill Information Systems Co., 1980); Building Construction Cost Data, 38th Annual Edition (Robert Snow Means Co., Inc., 1980).

Storage

Storage volume must be calculated for the period that shows the greatest difference between user demand and source supply. If this difference is going to be great for an extended time each year, it might be more economical to switch to potable water for that time rather than to store large volumes of reclaimed water. Both options should be checked.

Large volumes of reclaimed water can be stored in man-made lakes, which also can be used to provide recreation if O&M funds are available. A cheaper form of storage is an earthen or lined lagoon. Concrete tankage can be used to store smaller volumes.

Capital costs of storage lagoons can be estimated by calculating (in cubic yards) the amount of earthwork necessary, and referring to the Means or Dodge Guides. Concrete tankage costs can be estimated as the sum of earthwork needed, plus the volume of concrete slab and concrete wall, in place. These figures are also available in the Means and Dodge Guides. In addition, these references provide information about other forms of storage -- such as steel and plastic tanks and elevated storage -- if special applications require them.

O&M costs on storage are negligible.

Treatment

Treatments that can be used between activities to remove specific pollutants include ion exchange, filtration, chemical coagulation, and chlorination. Capital costs for these processes vary widely depending on the flow rate to be treated, whether a package plant will suffice, how much site preparation must be done, and many other factors. Cost algorithms presented by the U.S. Environmental Protection Agency (USEPA) for treatment works generally do not include flows less than 1 mgd (3790 m^3) and cannot be extrapolated to lower ranges. A detailed description and cost analysis of the many options available to treat these types of flows is outside the scope of this work. Manufacturers should be contacted for rough cost estimates of treatment units needed for each specific application.

Estimates of labor and energy needed for operation of these treatment processes can be obtained from:

1. Estimating Staffing for Municipal Wastewater Treatment Facilities (USEPA, Office of Water Program Operations, 1973).

2. Energy Conservation in Municipal Wastewater Treatment, EPA 430/9-77-011 (USEPA, Office of Water Program Operations, March 1978).

Pumping

Pumping costs depend on both the capacity of the pump and the total head that must be developed. The head can be calculated using the energy equation which states that the head produced by the pump is proportional to the differences in pressure, velocity, and elevation between inlet and outlet, plus the frictional and other energy losses throughout the system:

$$h_p = \frac{P_2 - P_1}{\delta} + \frac{V_2^2 - V_1^2}{2g} + (Z_2 - Z_1) + h_L \qquad \text{[Eq 2]}$$

where:

h_p = head produced by pump, ft

P_2, P_1 = pressures, lbs/sq ft

δ = specific weight of fluid pumped = 62.4 lbs/cu ft for water at 60°F

V_1, V_2 = velocity of fluid in pipes = Q/A

Z_1, Z_2 = elevation, available from base map

h_L = head losses in the system due to friction, entrances, exits, etc.

g = gravitational constant.

Once the head that must be developed has been estimated by this method, a manufacturer can be called for a rough estimate of the capital cost. The maximum and minimum flows that the pump must handle, as well as the head it must develop, are all factors that influence the type of pump chosen.

The manufacturer can supply information about the efficiency of the specific pump recommended at the various flow rates it will handle. This information can be used to calculate power consumption using the following equation:

$$HP = \frac{Q\delta H}{550e} \qquad \text{[Eq 3]}$$

where:

HP = horsepower required
Q = flow rate, cu ft/sec
δ = specific weight, lbs/cu ft
H = head produced, ft
e = efficiency of pump

This can be converted to kWh per year:

$$\text{kWh/yr} = \left(\frac{\text{HP}}{0.75\ \text{HP/kW}}\right)\left(\frac{\text{hrs pumping}}{\text{year}}\right) \qquad [\text{Eq } 4]$$

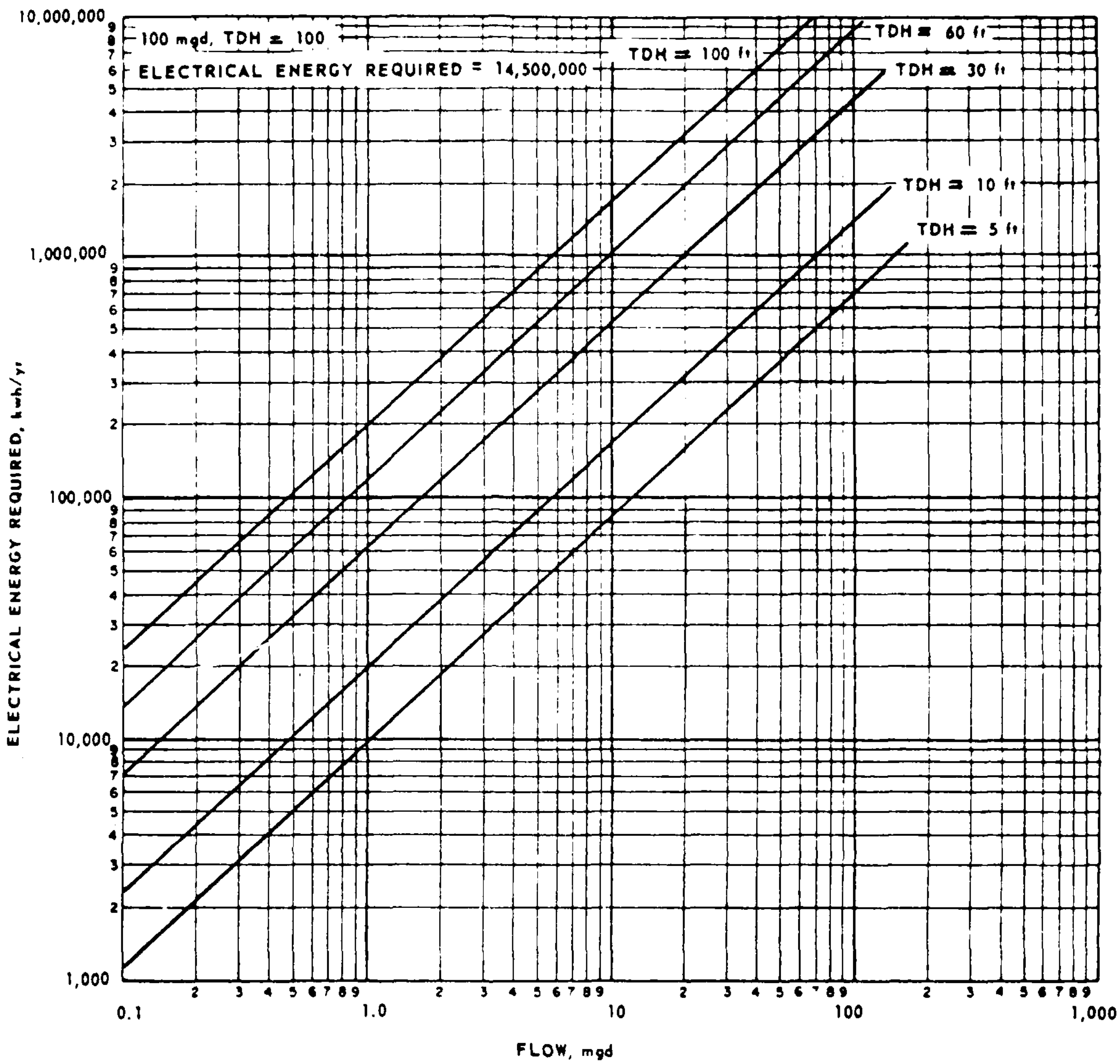
An alternative to these calculations is to use the curves presented by the USEPA for electrical consumption of raw sewage pumping. These are illustrated in Figures 9 through 11.[5] An estimate of maintenance hours required can be extrapolated from Figure 12.

Total Costs

The capital costs and O&M costs should be totaled for the whole network. The total yearly cost can be found by dividing the capital costs, including interest of the components, by their expected lifetimes to get dollars per year, and adding that to the annual O&M cost.

This total yearly cost can be compared to the annual water and sewage dollar savings of the reuse network. Networks that have a total yearly cost equal to or less than the yearly savings anticipated should be pursued under Stage 3 of the model, as described in Chapter 5.

[5] These figures are from Energy Conservation in Municipal Wastewater Treatment, EPA 430/9-77-011 (USEPA, Office of Water Program Operations, March 1978).



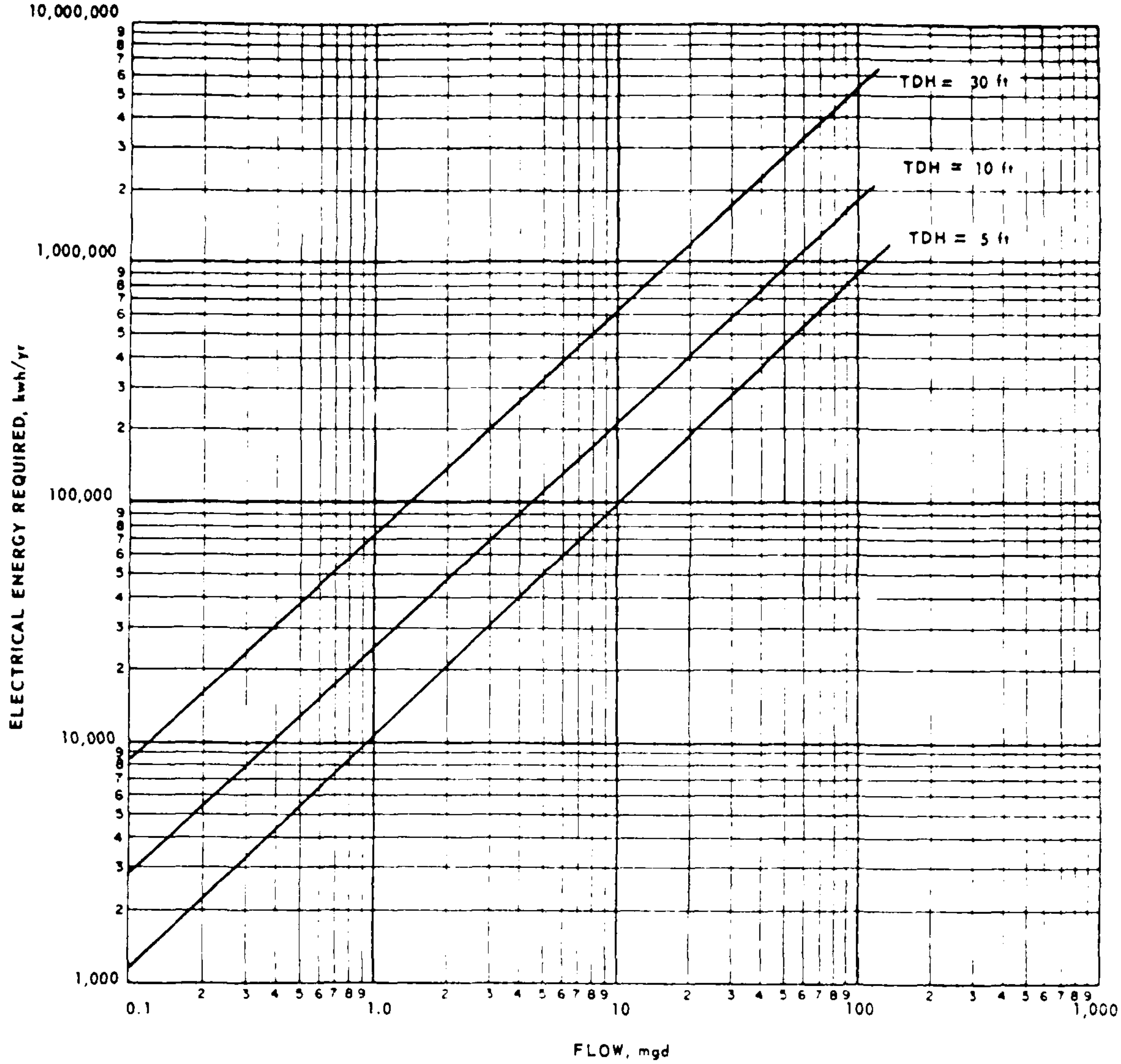
RAW SEWAGE PUMPING (CONSTANT SPEED)

Design Assumptions:

Efficiencies for typical centrifugal pumps (varies with flow)
Variable level wet well
TDH is total dynamic head

Type of Energy Required: Electrical

Figure 9. Raw sewage pumping (constant speed). (From Energy Conservation in Municipal Wastewater Treatment, EPA 430/9-77-011 [USEPA, Office of Water Program Operation, March 1978].)



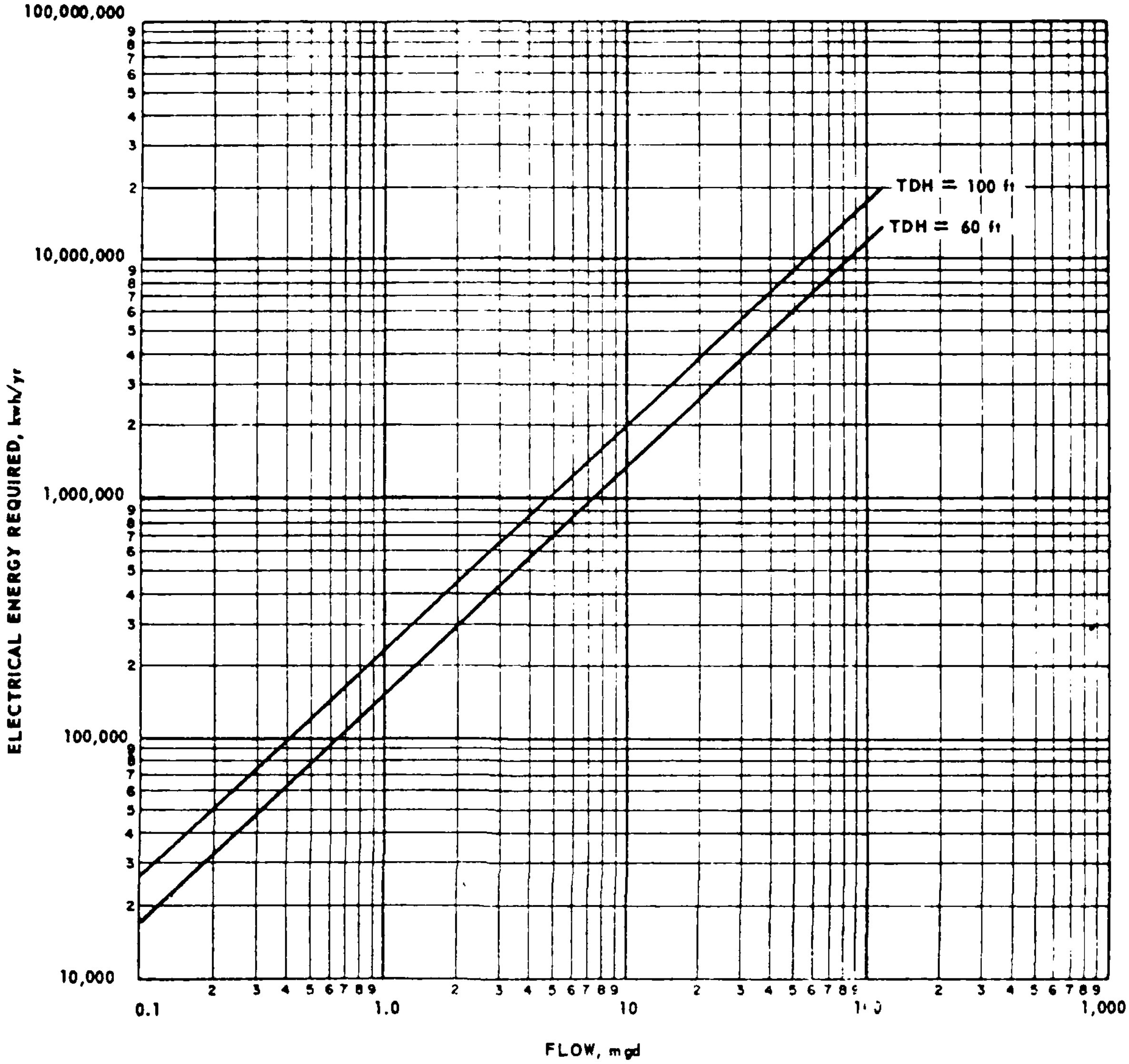
RAW SEWAGE PUMPING (VARIABLE SPEED)

(Curve 1 of 2)

Design Assumptions:
- Efficiencies for typical centrifugal pumps (varies with flow)
- Wound Rotor variable speed
- Variable level wet well

Type of Energy Required: Electrical

Figure 10. Raw sewage pumping (variable speed, curve 1). (From Energy Conservation in Municipal Wastewater Treatment, EPA 430/97-77-011 [USEPA, Office of Water Program Operations, March 1978].)



RAW SEWAGE PUMPING (VARIABLE SPEED)

(Curve 2 of 2)

Design Assumptions:
- Efficiencies for typical centrifugal pumps (varies with flow)
- Wound rotor variable speed
- Variable level wet well

Type of Energy Required: Electrical

Figure 11. Raw sewage pumping (variable speed, curve 2). (From Energy Conservation in Municipal Wastewater Treatment, EPA 430/97-77-011 [USEPA, Office of Water Program Operations, March 1978].)

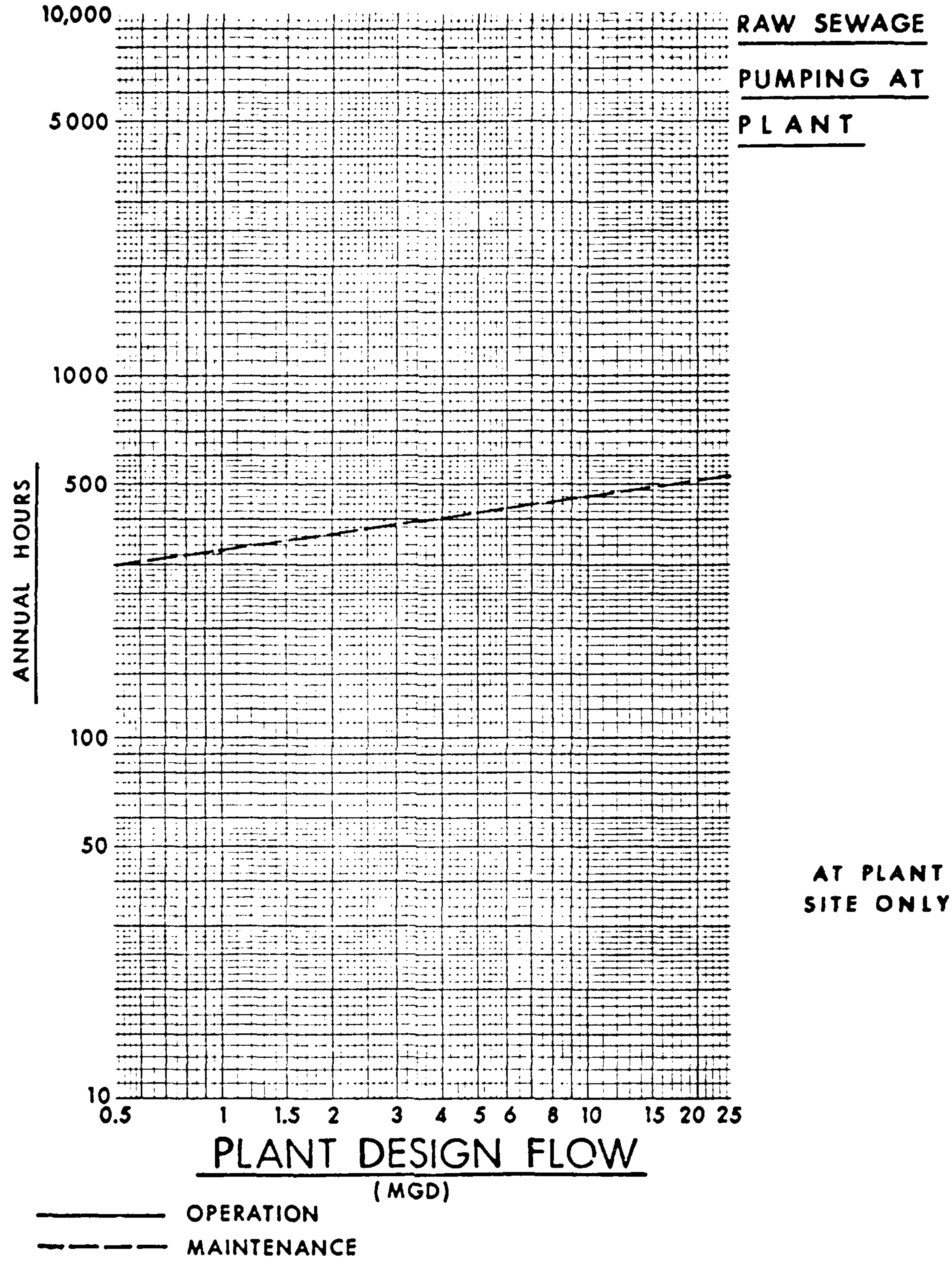


Figure 12. Curve for estimating maintenance hours. (From Estimating Staffing for Municipal Wastewater Treatment Facilities [USEPA, Office of Water Program Operations, 1973].)

5 STAGE 3: WASTEWATER SURVEYS

So that the output from the computer system (Chapter 6) can be used as a basis for preliminary design, actual water quality and flow data must be input for each activity under consideration. Therefore, a wastewater survey must be done on post -- unless data are available from very recent and very complete testing. Because of the great expense of this type of testing, Stage 3 analysis should be done only for the most promising networks.

Detailed descriptions of wastewater surveying protocols are available in the professional literature.[6]

The following general survey tasks are completed during an in-depth base visit (20 to 30 man-days):

1. Interviews with base personnel to expand Stage 2 data.

2. Composite and grab sampling of all activities without good existing data. This, along with interviews, should yield complete activity descriptions.

3. Survey of the base for location of possible new treatment, storage, or pumping facilities, and best location for reclaimed water pipelines.

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[6] An excellent reference on this subject is Modern Pollution Control Technology, Volume 2 (Water Pollution Control and Solid Waste Disposal Research and Education Association, 1978). Chapter 1 of this publication contains sampling and flow measuring data.

6 THE COMPUTER SYSTEM

After the wastewater survey has been completed, a computer program can be used to compare reuse networks. The program is divided into two separate phases. Output from Phase I (Activity Description) is intended to help the evaluator select feasible activity cascade networks from those that remain after Stage 2 analysis. Phase I assimilates installation activity data supplied by the user and prints out several forms for each activity showing flow patterns, effluent quality after various levels of treatment, the effects of recommended pretreatment units, and cascade potential.

Phase II (Network Feasibility) evaluates the networks selected. Output provides a comprehensive network description including the requirements for piping, pumping, storage, and treatment facilities, and finally the total cost of the entire cascade system. Continued modification of the most cost-effective cascade networks should lead to an optimum reuse system for an installation.

Use of the computer program requires the following tasks:

1. Complete all input data for the computer program (Phase I).

2. Run Phase I of the computer program.

3. Complete conceptual networks and other Phase II computer program input.

4. Run Phase II of the computer program.

5. Complete evaluation and make conclusions and recommendations.

The computer program is not to be used for final design and costing, but rather as a tool to efficiently compare the overall estimated costs of selected reuse schemes. The computer program is based on work performed by SCS Engineers for the Air Force.[7]

The computer system does not require the services of a programmer, but it does require an environmental engineer to evaluate interim computer output and to make decisions as to appropriate reuse networks for testing. The engineer must also evaluate final cost figures, adjust for existing equipment, and make other engineering judgments. The computer program does not provide accurate cost data; rather it is a means of comparing various networks.

All program documentation can be found in the users' manual published by SCS Engineers.[8] This reference includes a complete description of and layout for the Stage 3 computer program data and a copy of the reuse computer program.

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[7] SCS Engineers, Cascade System for Water Reuse at Air Force Installations, CEEDO-TR-77-19 (U.S. Air Force, October 1976).

[8] Curtis J. Schmidt, Ernest V. Clements, and Leanne Hammer, Subpotable Water Reuse at Army Fixed Installations: A Systems Approach, Volume II (SCS Engineers, August 1979).

The computer model requires input from the evaluator in two areas. Initially, activity data as well as treatment efficiencies must be provided for all treatment processes to be considered. After the first phase of the program is complete, the evaluator must input various reuse systems that he/she wishes to test. The evaluator must have access to a computer that can accept the program's language and that has enough memory storage. The program is written in American Standard Fortran IV, and was originally tested on a CDC 6500 computer. The program is large and requires about 260,000 bytes of computer core.

7 CONCLUSION

The wastewater reuse model component will allow the Army (1) to assess quickly an installation's potential for water reuse and (2) to identify the most cost-effective reuse networks for an installation.

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APPENDIX A:

WHITE SANDS MISSILE RANGE FIELD TEST

Stage 1, Part 1

In February 1980, White Sands Missile Range (WSMR) was initially considered as a possible site to field test the wastewater reuse model. AEHA Regional Division North determined through preliminary telephone conversations with WSMR environmental personnel that the groundwater supply was being withdrawn at a faster rate than it was recharging, and that a large volume of water was being used for landscape irrigation. In March 1980, the site was visited by personnel from CERL, AEHA-Aberdeen, and AEHA-North. For information about WSMR, the reuse team had to rely on published reports, and on conversations with the personnel involved in various activities. The following references were used; these gave detailed information on the water supply, water and wastewater treatment plants, environmental factors, energy costs of water production, and the golf course.

1. Annual Water-Resources Review (U.S. Department of the Interior Geological Survey, open file 78-985, 1978).
2. Water Resources Development, Analytical Report (AR) 210-20 (Director of Facilities Engineering, WSMR, December 1978).
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5. Restoration and Repair of Nine-Hole Golf Course, Document #WS-50-79 (Facilities Engineering Directorate, WSMR, February 1979).
6. Installation Environmental Impact Assessment (DA, USAWSMR, March 1976, revised May 1978).

The information for Stage 1 comes from these references, except where noted.

1. Water Supply and Treatment

The base's water supply is being mined from an aquifer 400 ft (122 m) below the surface. The aquifer is potable to a depth of 2500 ft (762 m) at the west boundary of the post, the Organ Mountain Range. It decreases in thickness as it extends to the east; 4 mi (6.4 km) east of the post area, the aquifer becomes totally saline alluvial fill (Figure A1).

The estimated lifetime of the potable aquifer is 25 to 100 years. Natural recharge of the potable aquifer has been estimated at 825 acre-feet (10^6 m^3) per year. This is about one third of the current annual withdrawal.

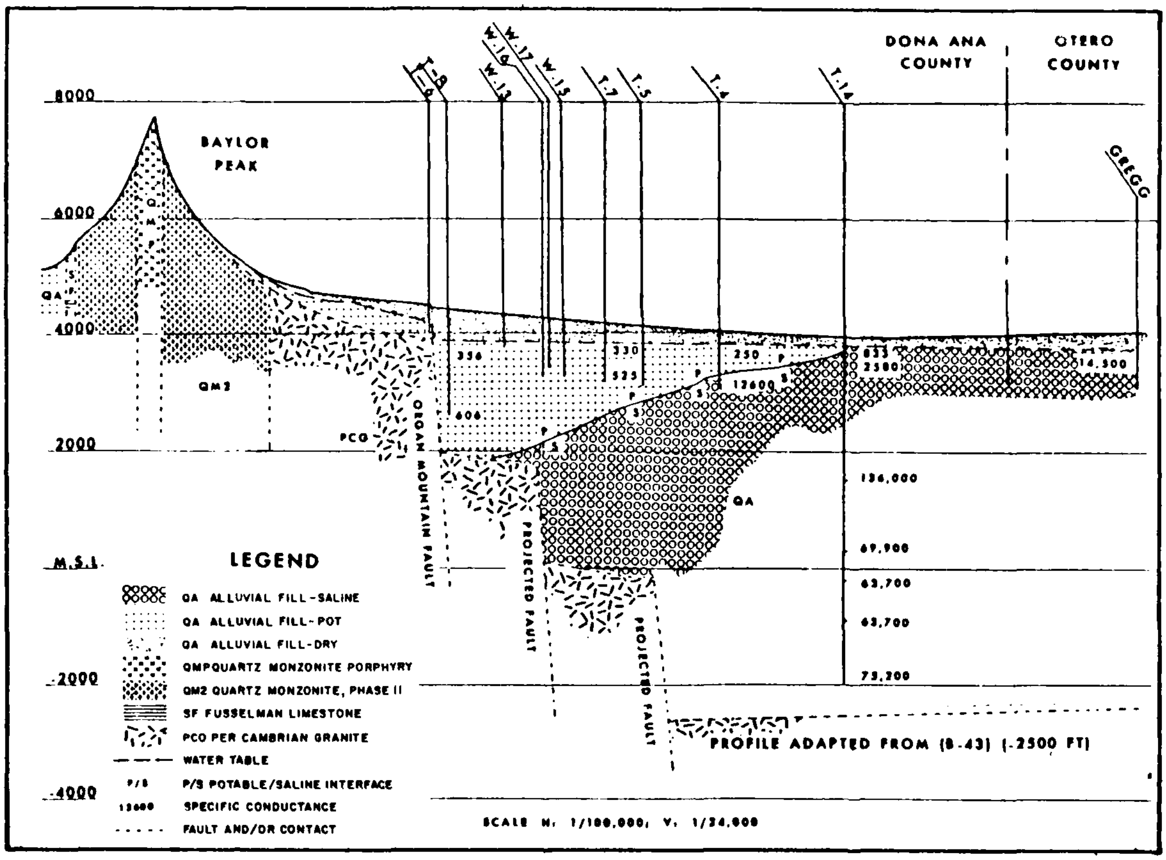

Figure A1. Cross section through well field. (From Water Resource Development, Analytical Report [AR] 210-20 [Director of Facilities Engineering, WSMR, December 1978].)

The lifetime of the aquifer can be extended if the water is mined evenly instead of from one area; this will lessen saltwater intrusion due to excessive drawdown in one small portion of the aquifer. Adjacent watersheds also have potential for development; this would contribute to lengthening the life of the current supply.

Routine testing of the water supply is not done at the WTP; however, the quality of both the potable water and the water supply is well documented by special studies performed because of continuing concern over the future availability of usable water (Table A1). Average monthly usage is 3.3 mgd (12 500 m^3) with a peak usage in June and July of 4.9 mgd (18 600 m^3). Monthly and yearly pumpage from the 11 wells north of the post from 1964 through 1978 is presented in Figure A2. These bar graphs show that 70 percent of the total annual usage occurs between April and August. This consumption pattern is due mainly to heavy irrigation demands during the summer months.

Since the water supply is of such good quality, sedimentation followed by chlorination is the only treatment provided. From the WTP, the water is pumped to two 400,000 gal (1.52 x 10^6 L) ground-level storage tanks. Additional storage is provided by two 1 MG (3.79 x 10^6 L) and one 0.2 MG (758 000 L) elevated storage tanks (see Figure A3).

Costs of water production are currently $1.17/1000 gal ($0.31/1000 L); most of this amount is spent for electricity to pump the groundwater from an average depth of 450 ft (137 m). Capital and administrative costs are not included in this figure.

No expansion or upgrading of the water supply system is planned. The sedimentation process at the plant has a capacity of 6000 gpm (22 740 L/min). This is well above the 4.9 mgd (18 600 m^3) peak demand. In 1974, water conservation measures were enforced to reduce peak electrical demand: no landscape irrigation is permitted between 10 a.m. and 4 p.m. Monday through Friday. This restriction extends to the golf course. In addition, a computer-controlled sprinkler system was installed at the golf course to allow control and measurement of the water usage. As a result of these measures, annual water usage for 1977 was the lowest since 1963, while the population on the post remained fairly constant (about 4600).

There are no plans that would cause WSMR's mission, activities, or effective population to change greatly in the future. However, since the major cost of the water supply is pumping, future costs are sure to increase as electrical costs rise, and as water must be drawn from greater depths.

2. Wastewater

The wastewater treatment facility servicing the Main Post area is a trickling filter plant 1.5 mi (2.4 km) southeast of Post Headquarters (HQ). This facility was built in 1958 with a design capacity of 1 mgd (3790 m^3). The process train is presented in Figure A4. The wastewater flows by gravity through the plant to an open channel where it percolates into the soil mantle.

The plant does not have an NPDES permit due to the conditions to which it discharges. No particular discharge quality has been specified by either the New Mexico EPA or the USEPA. The performance of the plant is very good. It

Table A1

Chemical Analyses of Composite Samples of Post Water Supply (From Water Resources Development, Analytical Report [AR] 210-20 (Director of Facilities Engineering WSMR. December 1978.)

Date of Collection		(ppm) Jul 1955	(ppm) Jul 1964*	(ppm) Aug 1976**
Silica	(SiO_2)	40.	41.	28.1
Iron	(Fe)	0.04	0.04	0.06
Manganese	(Mn)	-	-	0.02
Calcium	(Ca)	35.	35.	39.3
Magnesium	(Mg)	9.1	7.5	7.6
Sodium	(Na)	21.	29.	28.7
Potassium	(K)			2.4
Bicarbonate	(HCO_3)	128.	130.	-
Carbonate	(CO_3)	0	0	-
Sulfate	(SO_4)	44.	50.	65
Chloride	(Cl)	10.	11.	19.7
Fluoride	(F)	0.4	0.4	0.4
Nitrate	(NO_3)	3.3	3.2	1.35+
Dissolved Solids, Calculated		225.	241.	264.
Hardness as $CaCO_3$		121.	115.	134.
Noncarbonate hardness, $CaCO_3$		15.	15.	-
Alkalinity as $CaCO_3$		-	106.	106.
Specific Conductance (micromhos at 25°C)		330.	358.	430.
pH		7.5	7.4	7.93

*Analyses by USGS, Water Resources Division, Albuquerque, NM.
**Analysis by AEHA, Fitzsimmons Army Medical Center, Denver, CO.
+Nitrates, as nitrogen.

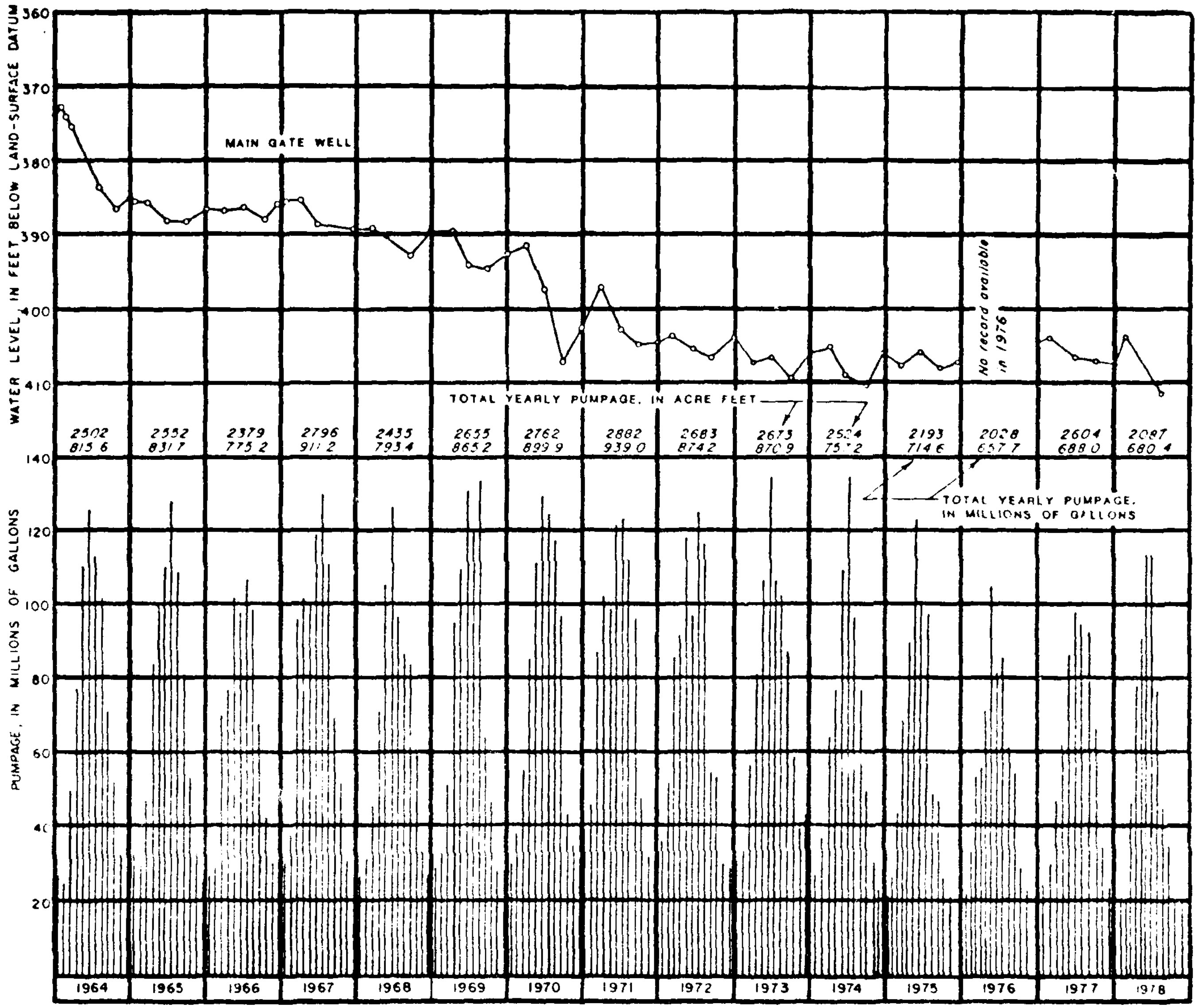

Figure A2. Monthly and yearly pumpage in the post headquarters well field. (From Annual Water-Resources Review [U.S. Department of the Interior Geological Survey, open file 78-985, 1978].)

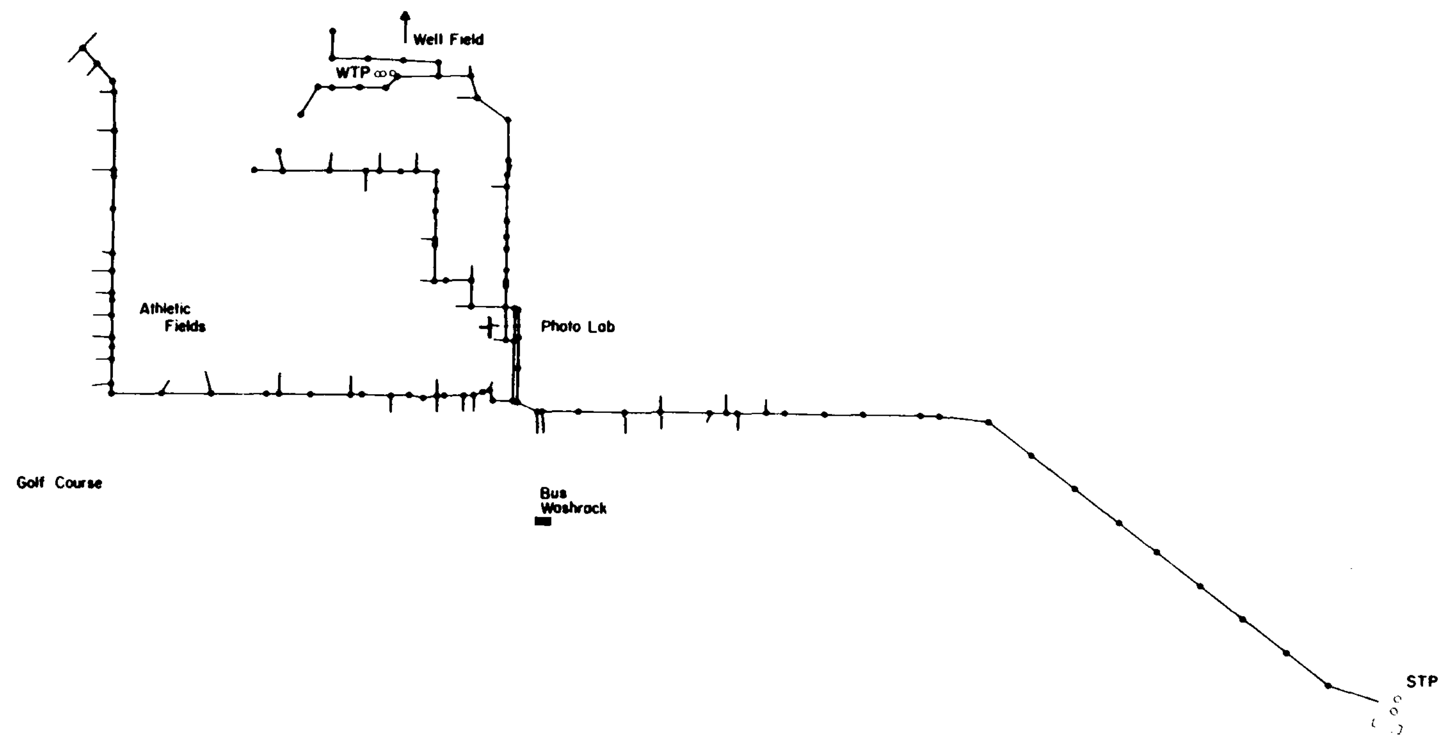

Figure A3. WSMR facilities.

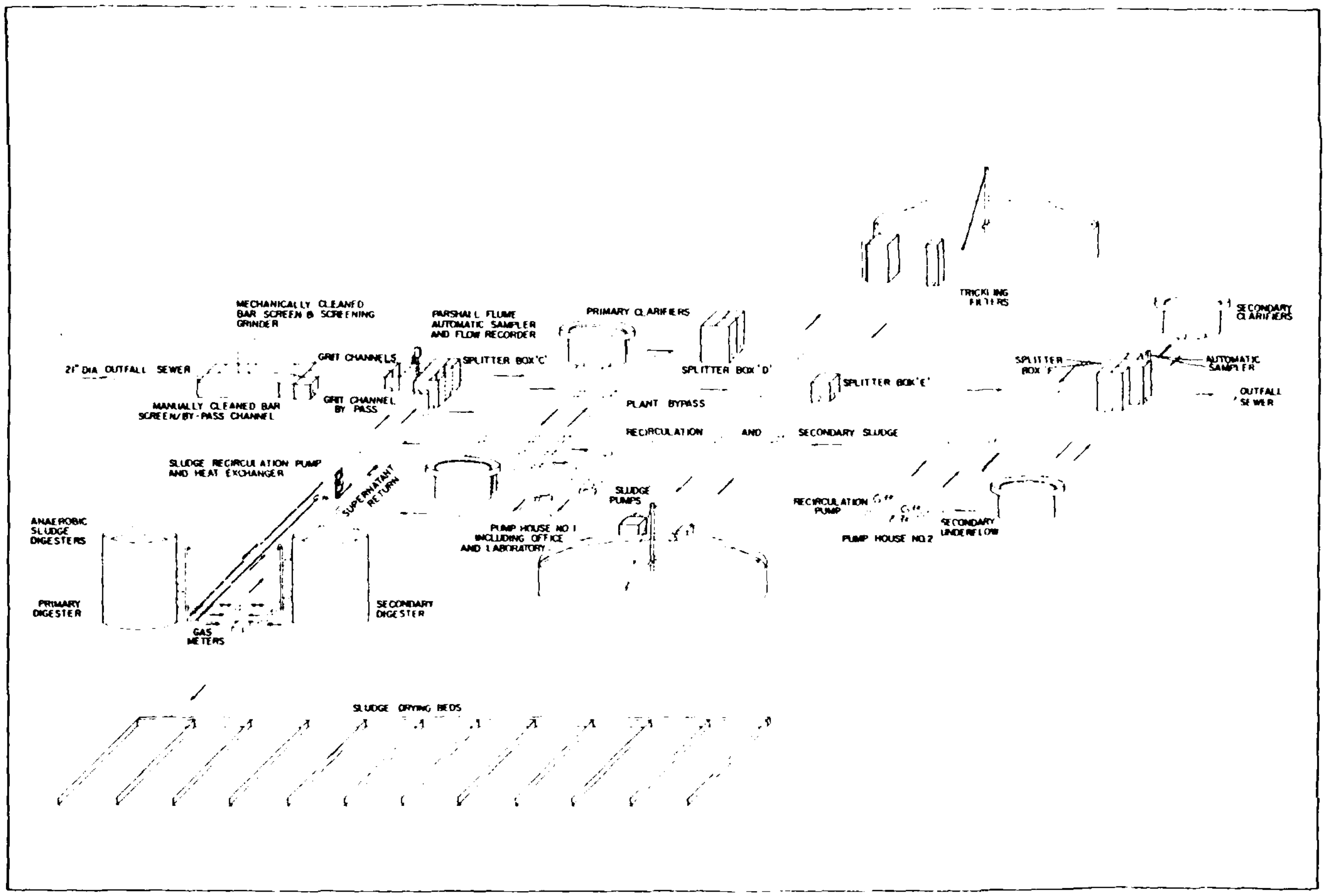

Figure A4. WSMR wastewater treatment plant. (From Wastewater System Analysis, U.S. Army, WSMR [prepared by Higgenbotham & Associates, and Gilbert, Meyer, and Sams, both of Colorado Springs, CO., August 1979].)

averages 85 percent BOD removal; the mean effluent quality is 20 mg/L BOD. A mean solids removal of 90 percent provides an average effluent quality of 12.6 mg/L SS. Nitrogen compounds are not measured.

The average flow through the plant is about 0.58 mgd (2200 m^3). The range of average daily flows and their mean for the period 1971-1978 are shown in Figure A5.

Expanding or upgrading the plant, discharging to a regional sewage system, and accepting wastewater from surrounding communities are not planned.

There is no industrial waste treatment plant on post; however, there are a number of laboratories and operations that discharge industrial-type wastes to the trickling filter system. A description of these facilities and their wastes is presented in Stage 1, Part 2 (p 60). According to one report, "Normal operations of these technical activities do not pose a serious threat to reasonable performance of the treatment works. Accidental discharge of large quantities of a variety of chemicals could cause complete plant upset and failure; however, it appears that adequate housekeeping, training, and professional conduct on the part of the staff has served to minimize this potential."[6]

3. *Institutional Factors*

No laws or agreements regulate withdrawal of groundwater or volume of wastewater discharge.

Internal recycle is being practiced at the large photo lab. This will be described in greater detail in Stage 1, Part 2.

The base commander is interested in using reclaimed water if it will lead to a reduction in energy consumption.

4. *Environmental Factors*

The average monthly precipitation* in Albuquerque, NM (200 mi [320 km] north of WSMR main post area) is as follows:

J	F	M	A	M	J	J	A	S	O	N	D
0.4	0.4	0.5	0.5	0.8	0.6	1.2	1.3	1.0	0.8	0.4	0.5
(10.2)	(10.2)	(12.7)	(12.7)	(20.3)	(15.2)	(30.5)	(33)	(25.4)	(20.3)	(10.2)	(12.7)

The values are in inches (millimeters) and are based on 30 years of records.

The average monthly reservoir evaporation in Roswell, NM (100 mi [160 km] east of WSMR), computed in inches (millimeters), is:

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6 Wastewater System Analysis, U.S. Army WSMR (prepared by Higginbotham & Associates, and Gilbert, Meyer, and Sams, both of Colorado Springs, CO, August 1979).

* Precipitation and evaporation data were taken from David Keith Todd, ed., The Water Encyclopedia (Port Washington, NY: Water Information Center, 1970).

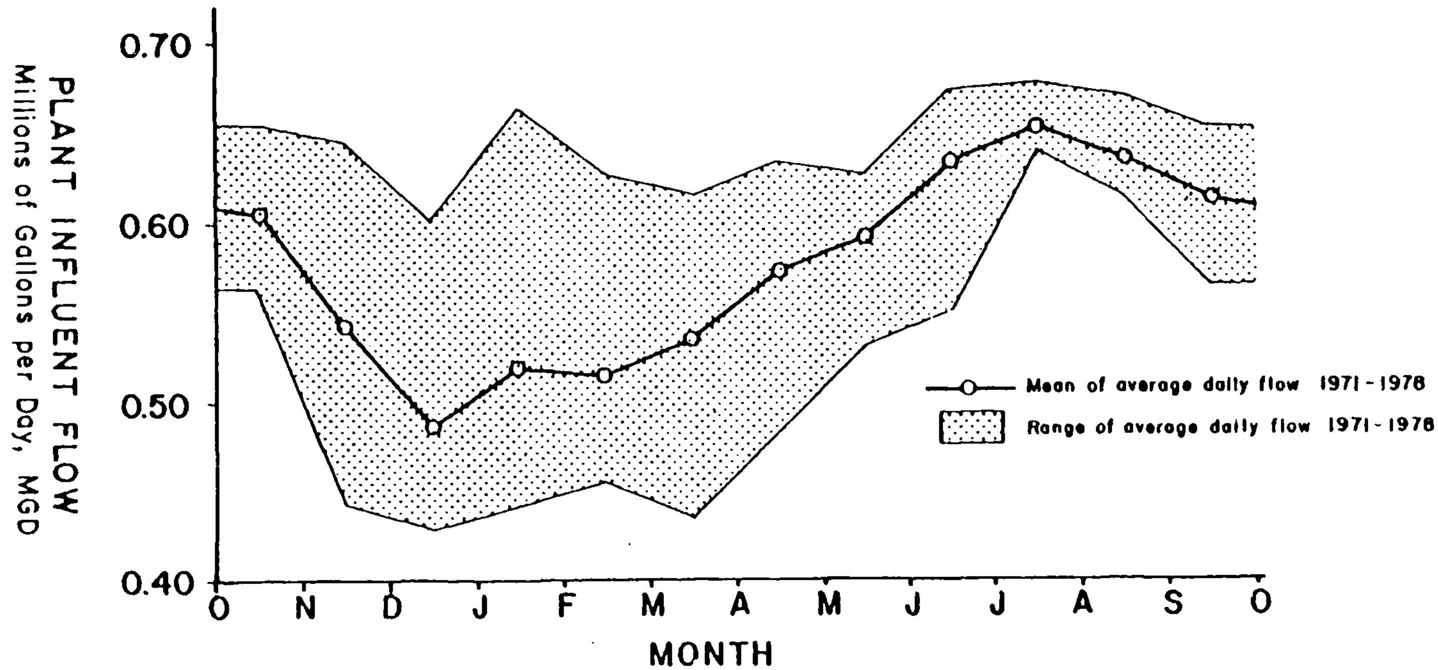

Figure A5. Comparison of mean/average daily flows (from Wastewater System Analysis, U.S. WSMR [prepared by Higginbotham & Associates, and Gilbert, Meyer, and Sams, both of Colorado Springs, CO, August 1979].)

J	F	M	A	M	J	J	A	S	O	N	D
2.1	3.2	4.9	6.8	8.3	9.8	9.4	8.3	6.9	5.5	3.5	2.5
(53.3)	(81.3)	(124.5)	(172.7)	(210.8)	(248.9)	(238.8)	(210.8)	(175.3)	(139.7)	(88.9)	(63.5)

The State of New Mexico has groundwater protection regulations that provide standards for irrigation water.[10]

5. Energy

WSMR is a U.S. Army Test and Evaluation Command (TECOM) installation; breakdowns of water and sewage treatment costs were not available. An experiment done 25 June 1975 showed that the WSMR facility used 1500 kVA over an 8-hour period to produce and store 5.34 MG (20.2 ML) of potable water (Figure A6).[11]

El Paso Electric Company provided the WSMR conversion factor between kVA and kW. Electricity needed for water production was calculated as:

$$[(1500 \text{ kVA})(0.998 \text{ kW/kVA})(8 \text{ hours})]/5.34 \text{ MG}$$
$$= 2.243 \text{ kWh/1000 gal } (0.59 \text{ kWh/1000 L})$$

As water must be pumped from greater and greater depths, electricty usage will increase. Electricity is not produced on post, and there are no plans to do so.

WSMR has taken steps to cut electricity costs without cutting overall usage by reducing use during peak hours (8 a.m. to 4 p.m.). No lawn sprinkling is allowed, the golf course is watered at night, and the wells and the central booster pump at the WTP are not operated between these hours.

Data Analysis

The present aquifer will be adequate in the near future, and other watersheds are available for development. However, the available supplies, while containing enough water, are all expensive to produce due to their depth.

The WTP, STP, and well field are operated at about half of their capacities. The effective population of the post is not expected to change. Therefore, barring failure, no new supply or treatment works will be necessary.

A literature search was done to identify tolerable water quality for landscape irrigation (see Table A2). The STP effluent will have to be better characterized than it is presently; however, it meets even the most stringent BOD and SS requirements. Obviously, chlorination will be necessary.

The volume of wastewater is low; it averages 0.58 mgd (2200 m^3) and shows very little seasonal fluctuation. Water is supplied to the post at an average rate of 1 mgd (3790 m^3) from October through March and 2.9 mgd from April through September. Therefore, 58 percent of the potable water produced is

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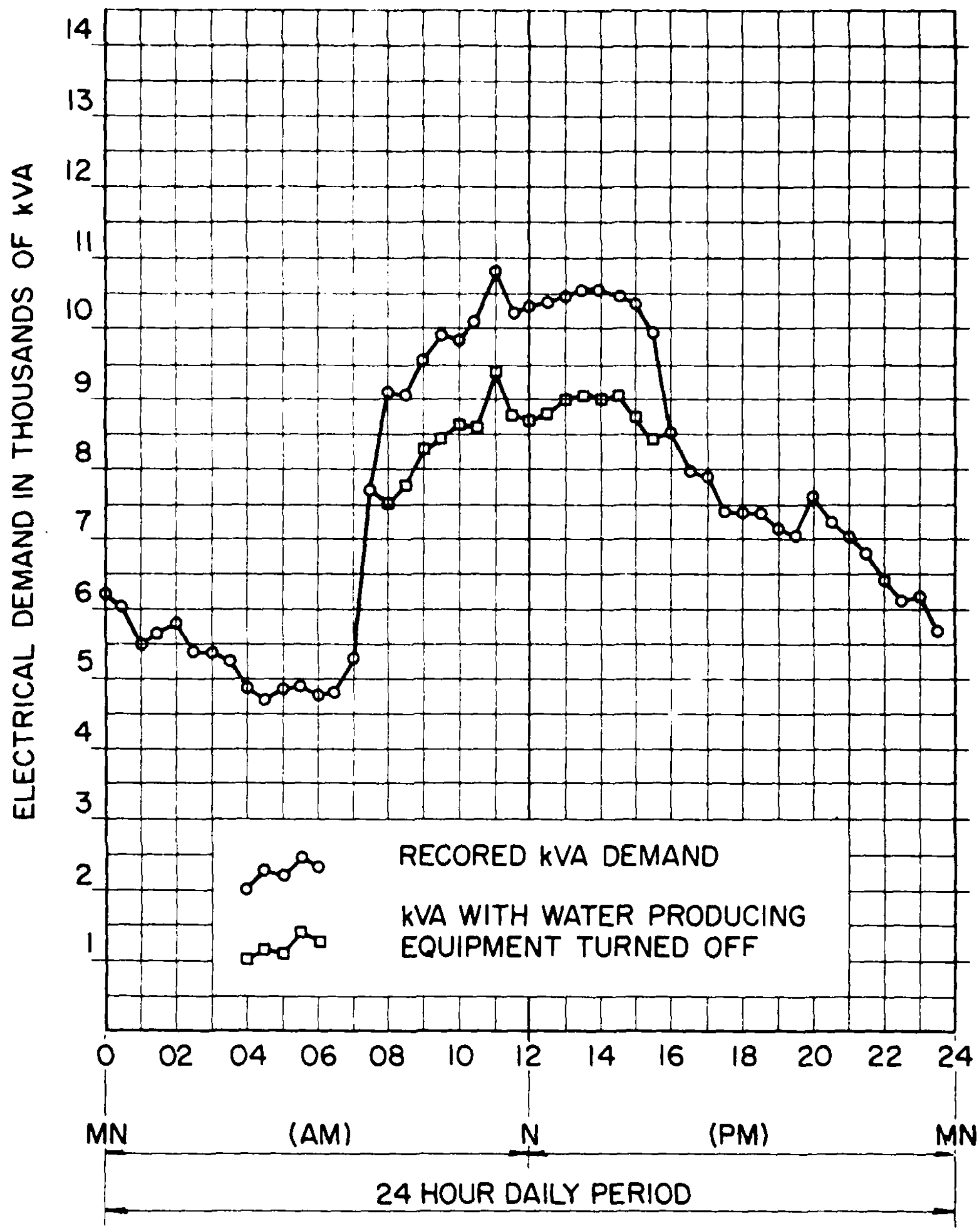
[10]New Mexico Water Quality Act (Chapter 326, Laws of 1973, as amended).
[11]Water Resources Development, Analytical Report (AR) 210-20 (Director of Facilities Engineering, WSMR, December 1978).



HOURLY kVA DEMAND: PEAK--10,805; HOUR--1100

LOCATION: POST AREA

DATE: 25 JUNE 1975, WEDNESDAY

Figure A6. Hourly kVA demand.

Table A2

Tolerable Water Quality According to Various References

Constituent	Tolerable Concentration, mg/L, by Source, for Irrigation						
	(Numbered headings refer to references listed following table.)						
	1	2	3	4	5	6	7
BOD_5	30	--	--	20	--	30	--
COD	60	--	--	--	--	--	--
TOC	--	--	--	--	--	--	--
phenols	0.5	--	--	50	--	0.5	--
SS	50	--	--	15	--	15	--
TDS	2000	--	500	--	1600	750	500
O and G	30	--	--	nil	--	10	--
Cl	350	--	100	100-200	200	175	250
NO_3	10	--	--	--	--	30	--
NH_4	20	--	--	--	--	--	--
PO_4	N.S.	--	--	--	--	--	--
Na	350	--	--	--	--	--	--
Ca	--	--	--	--	--	--	--
$CaCo_3$	N.S.	--	--	--	--	--	--
B	3.0	--	0.5	--	0.75	1.5	--
CN	0.01	--	--	--	--	.1	--
Fe	10	5.0	--	5.0	5.0	--	--
pH	4.5-9.0	4.5-9.0	7-8.5	6-9	--	--	--
Coliform	23/100 ml	--	1000/100 ml	2.2/100 ml	--	200/100 ml	--
Al	--	5.0	--	5.0	5.0	--	--
Cd	--	0.01	--	0.01	0.01	--	--
Cr	--	0.1	--	0.1	0.1	0.005	--
Co	--	0.05	--	0.05	0.05	--	--
Cu	--	0.2	0.1	0.2	0.2	.2	--
Pb	--	5.0	--	5.0	5.0	--	--
Zn	--	2.0	--	2.0	2.0	.3	--
SAR	--	--	6.0	8-18	6-8	--	--
umhos/cm	--	--	750	--	2500	--	--
RSC*	--	--	1.25	--	--	--	--
As	--	--	1.0	0.1	0.1	0.01	--
SO_4^{-2}	--	--	200	200-400	--	250	250
F	--	--	--	2.0	1.0	--	--
Li	--	--	--	2.5	.075	--	--
Mn	--	--	--	0.2	0.2	--	--
Mo	--	--	--	0.01	0.01	--	--
Ni	--	--	--	0.2	0.2	0.1	--
Se	--	--	--	0.02	0.02	--	--
V	--	--	--	0.1	0.1	--	--
Be	--	--	--	--	0.1	--	--

*Residual sodium carbonate

Table A2 (Cont'd)

References

1. Curtis J. Schmidt, Ernest V. Clements, Leanne Hammer, Subpotable Water Reuse at Army Fixed Installations: A Systems Approach, Volume I, ADA075159 (SCS Engineers, supported by U.S. Army Medical Research and Development Command, August 1979).

2. W. W. Eckenfelder, Principles of Water Quality Management (CBI Publishing Co., 1980), p 11.

3. David K. Todd, ed., The Water Encyclopedia, Sec. E, "Irrigation Quality," (Port Washington, NY: Water Information Center, 1970), pp 331-4.

4. Municipal Wastewater Reuse News, American Water Works Association (AWWA) Research Foundation, No. 29 (February 1980), p 13.

5. William R. Everest and Robert A Paul, "Reclaimed Wastewater as a Feasible Water Resource for Landscape and Orchard Irrigation," in Water Reuse Symposium Proceedings, Vol III (AWWA Research Foundation, March 1979), pp 2098-2099.

6. California Regional Water Quality Control Board Standards, from Curtis J. Schmidt, Ernest V. Clements III, and Stephen P. Shelton, "A Survey of Practices and Regulations for Reuse of Water by Groundwater Recharge," AWWA Journal (JAWWA) (March 1978), p 145.

7. California State Health Department Standards, in Schmidt, et al., "Survey," p 146.

returned as sewage from October through March; only 20 percent is returned from April through September. These figures reflect the tremendous volumes of water being used for irrigation in the spring and summer.

High consumptive use of expensive water is the main reason to proceed to Part 2 of Stage 1.

Stage 1, Part 2

The following information was obtained by interviews with base personnel. See Figure A3 for the location of activities.

Bus Washrack

WSMR has 37 buses, but only 17 are in constant use for the commuter runs to El Paso. These 17 are washed once every 2 weeks on the average, depending on the weather. The other 20 buses are rarely washed. The post motor pool could not estimate the amount of water use.

Information obtained at Fort Campbell indicates that it takes 450 gal (1706 L) of water when a troop carrier helicopter is washed, inside and out with a garden hose. Obviously, this equipment is not comparable to the bus washrack at WSMR, which has spray nozzles on three sides. (Flow estimation with a bucket and stopwatch was not possible on this apparatus due to its structure.) But the amount of water needed to wash a bus and a helicopter should be roughly comparable. Using a conservative estimate of 1000 gal (3790 L) to wash one bus (more than twice that needed for one helicopter), WSMR could save 17,000 gal (64 430 L) every 2 weeks. At $1.17 for 1000 gal ($0.31/1000 L), the savings would amount to $20 every 2 weeks, or $500 a year. For this reason, and because of the washrack's isolated location, it was discounted as either a source or sink of reclaimed water.

Boiler Plant in Tech Area

Building 1544 contains three small boilers that produce steam to provide heat and hot water for eight or nine buildings in the tech area. There is no operator for this very small facility. The plant capacity is 15 x 10^6 Btu. According to Utilities personnel, blowdown is not constant. When solids increase to a predetermined level, the boilers are completely dumped and refilled. This occurs about once a month. Personnel did not know the capacity of the boilers.

The only water-using activity near the boiler plant is the photo processing facility. Both the boiler plant and the photographic laboratories need an extremely high-quality influent, and both produce a highly contaminated effluent. There are no irrigated areas near either facility. For these reasons, and because of the extremely erratic nature of the effluent flow, the boiler plant will not be considered in any reuse networks.

Photographic Facilities

Photographic processing is a major technical activity, performed mostly in Buildings 1512 and 1621. The motion-picture processing laboratories in Building 1512 produce both color and black and white finished film work. Maximum production runs may last as long as 8 hours per day, with one of the seven processing machines having been operated for 16 hours per day in the past. All processing machines have continuous wash water discharges. When all machines are operating simultaneously, it is possible that a maximum discharge rate of 400 gpm (1516 L/min) could occur.

A complete still photofinishing laboratory is in Building 1621, and can use five different photofinishing processes, three of which are automated. Peak production runs in this facility may reach 6 hours per day, though not on a daily basis. A total wash water flow rate of approximately 50 gpm (190 L/min) may occur.[12]

Personnel at the laboratory in Building 1512 reported that it is extremely rare for all processes to run simultaneously and that actual water usage is a fraction of values cited above and highly variable. Film is processed from 3 p.m. to midnight. Water usage data are not available; however, a log of the processes run versus time is kept, and water usage can be calculated from this.

Tap water filtered to 40 μm is used for all processes. Hardness must be added to the process water to avoid emulsion problems. Water conservation measures have been instituted at the facility. All developing solutions are reused throughout a shift, being continually refreshed when the concentration of developer falls beneath a certain level. A Kodak cascade process for reuse of rinse waters was installed in 1977. But at intervals, emulsion swelling occurred that could be attributed to nothing other than the cascade process; use of the system was discontinued in 1979. Ferricyanide bleaches are held and not discharged with the process effluents. There is some retention of cyanide in the washwater; however, the concentration is extremely small and not cause for concern in the waste treatment process. The silver is recovered by an electrolysis process and returned to a central reclamation facility in New Jersey.[13]

Golf Course

The golf course must be irrigated 4 months per year. 350,000 gpd (1300 m^3) are used every other day to water the whole course; 40,000 gpd (151 000 L/day) are used on the off-days to water greens and tees during July and August. During May and June, the whole course is watered every day. Water savings would amount to 34 MG (129 ML) a year or $39,000 a year. The maximum rate of use is 750 gpm (2843 L/min). The course is 3.5 mi (5.6 km) from the STP and 225 ft (69 m) above it.

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[12] Wastewater System Analysis, U.S. Army WSMR (prepared by Higginbotham & Associates, and Gilbert, Meyer, and Sams, both of Colorado Springs, CO, August 1979).

[13] Wastewater System Analysis, U.S. Army WSMR (prepared by Higginbotham & Associates, and Gilbert, Meyer, and Sams, both of Colorado Springs, CO, August 1979).

The course superintendent said that the soil does not have a high clay content and displays adequate percolation rates. On the other hand, the greens were specially built with sludge and Milorganite (Milwaukee's processed sludge) and percolate very little. The superintendent emphasized that the course needs soil tests and groundwater tests for existing quality.

An underground irrigation system and pump already exist. Application is controlled by a computer. The whole course is watered in 8 hours during the night to reduce peak electrical demand, and to avoid lowering the pressure in the family housing area, which is served by the same line.

Stage 2, Data Analysis

Only two activities are potential users of large volumes of reclaimed water: the photo lab and the golf course. The photo lab's needs are not as well defined and they vary from day to day as different processes are used. In addition, photoprocessing requires extremely high-quality water. Therefore, the photo lab may have potential for internal recycling.

Only one source of reclaimed water exists that is large, reliable, and fairly clean: the STP effluent. Electrical costs for pumping would be a large percentage of the total operating costs for a reuse network that provides STP effluent for golf course irrigation: the STP is 3.5 mi (5.6 km) east of and 225 ft (69 m) lower than the golf course. The potable water supply currently serving the course also requires a great deal of pumping: it is drawn from an average depth of 450 ft (137 m) through treatment and about 1 mi (1.6 km) of pipe to elevated storage 100 ft (30.5 m) above the ground. It is not obvious which system will have higher costs.

In addition, water can be provided not only to the golf course, but also to several areas along the pipeline that are not currently irrigated -- such as the teenclub ball fields, just north of the golf course, and the driving range at the course.

A schematic of the network is shown in Figure A7. To grow grass in New Mexico, 6.2 in. (157.5 mm) of water per month is needed.[14] This is equivalent to 0.2 in./day (5 mm/day). The volumes of water needed to irrigate areas other than the golf course have been calculated using this value.

The water savings at the golf course are:

(350,000 gpd)(92 days -- May, June, half of July, August)+(40,000 gpd)x(31 days -- half of July, August) =

34×10^6 gal per year potable water saved.

(34×10^6 gal [128.9×10^6 L] per year) ($1.17 for 1000 gal) = $39,000 per year

[14] David Keith Todd, ed., The Water Encyclopedia (Port Washington, NY: Water Information Center, 1970).

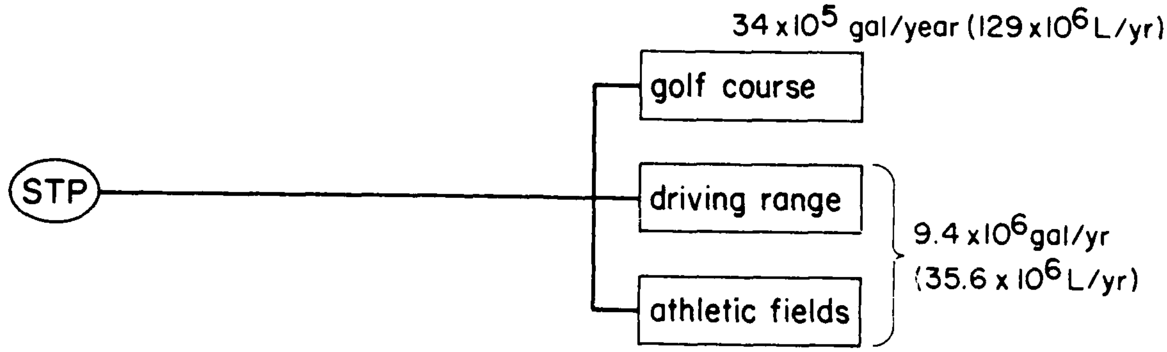

Figure A7. Schematic of reuse network.

The additional benefit of 9.4 x 10^6 gal (35.6 x 10^6 L) per year results from this reuse scheme for irrigating other areas. Since these areas are not currently watered, no dollar savings result. No savings in sewage treatment would occur.

The physical facilities required to implement this network must be more thoroughly defined before rough costing can be done. Since the pipe and pump sizes needed vary proportionately with the flow rate, the most economical way to build the system is to pump at a constant rate throughout the day. A total volume of 426,200 gpd (1.6 x 10^6 L/day) is needed for all areas to be irrigated. Storage of 500,000 gal (1.9 x 10^6 L/day) capacity will be provided in a lined earthen lagoon. The surface area of this lagoon should be minimized to reduce evaporation and algal growths. Design values of 10 ft (3 m) deep, 6700 sq ft (622 m^2) surface will be used. This lagoon can be built to provide a water hazard on the golf course if space is available. The maximum evaporation rate, experienced in June, is 9.8 in. (250 mm) per month. This is equivalent to 0.32 in. per day (.8 mm). Therefore, the maximum rate of evaporation from this lagoon would be about 1400 gpd (5306 L/day).

Assuming no other losses in the system, about 428,000 gpd (1.6 x 10^6 L/day) should be pumped to storage. This represents virtually all of the STP effluent available during the summer months (approximately 450,000 gpd [1.7 x 10^6 L/day]).

A constant volume will not be available at the STP, and the system must be sized to carry the peak flow coming from the STP or flow equalization must be built. Data on diurnal variations are not available from WSMR.

Pipe Costs

The pipe size needed to carry this flow is given by:

$$d^2 = \frac{4(1.0 \text{ cu ft/sec})}{\text{pi}(5 \text{ ft/sec})}$$

$$d = 0.51 \text{ ft} = 6.12 \text{ in. } (0.16 \text{ m})$$

Since piping is widely available in even diameters only, 8-in. (203-mm) pipe is needed: 200-psi asbestos cement pipe costs $9.43 per linear foot including the contractor's overhead and profit. PVC class 160 SDR-26 costs $8.60 per linear foot. PVC class 150 SDR-18 costs $12.20 per linear foot.[15]

Asbestos cement pipe is commonly used for this type of application. Total costs for such pipe would be.

$$(5280 \text{ ft/mi})(3.5 \text{ mi})(\$9.43/\text{ft}) = \$174,266$$

This does not include any valves that might be necessary. The pipeline can probably be placed on top of the ground over the open desert, very little excavation will be necessary.

Storage

A 10-ft-deep (3-m), 6670-sq-ft (622-m^2) lagoon will provide 1.5 ft (0.45 m) of sidewall above the water surface when the lagoon is full. This should be adequate. Approximately 2500 cu yd (1911 m^3) of earthwork are needed, this can be done with a crawler-mounted hydraulic backhoe.

A hoe with 3.5 cu yd (2.7 m^3) capacity can remove about 150 cu yd/hr (115 m^3) at a cost of $1.16/cu yd ($1.52/m^3). The earth can be dumped in the desert south of the course. A 20-cu-yd (15.3-m^3) dump trailer can haul 2.5 loads per hour over a 1-mi (1.6-km) round trip; three trailers, at an average cost of $1.04/cu yd ($1.36/m^3) per trailer, would be needed to keep up with the hoe. Therefore, total costs for digging the lagoon are about $5500. The lagoon must be lined to prevent percolation of the stored water. A 1/16-in.-thick (1.6-mm), nylon-reinforced neoprene sheet costs $1.80/sq ft $19.38/$m^2$). Lining the whole lagoon would cost about $18,000. Lining just the bottom and 1 ft (0.3 m) up on the sides would cost about $13,000.[16]

Total storage costs for a fully lined lagoon would be about $23,500.

Treatment

At a minimum, chlorination will have to be provided. This can be put in at the STP and used all year, or just during the irrigation season.

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[15] Figures are from <u>Building Construction Cost Data</u>, 38th Annual Edition (Robert Snow Means Co., Inc., 1980).

[16] Figures are from <u>Building Construction Cost Data</u>, 38th Annual Edition (Robert Snow Means Co., Inc., 1980).

Construction costs for a 0.5-mgd (1900 m^3) chlorination system are $35,000.[17] Also necessary are 15,000 kWh/yr, 400 hours of labor for operation and maintenance, and 22 tons (20,000 kg) of chlorine per year.[18] If the system is only used 4 months per year, the figures are reduced to 5000 kWh, 133 hours of labor, and 7 tons (6364 kg) of chlorine.

Pumping

At this point, there is not enough data on hourly flows at the STP outfall to allow a pumping system to be designed. However, the friction losses throughout the pipe network can be estimated, which will lead to an estimate of the power required.

The head loss due to friction in a pipe flowing full is expressed by:

$$h_L = (f)\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

where: h_L = frictional head loss, feet

f = friction factor

L = length of pipe, feet

D = diameter of pipe, feet

V = velocity in pipe, feet/sec

g = gravitational constant = 3.2 ft/sec^2.

Assume flow equalization is built at the STP outfall, so a constant pumping rate can be maintained. An equalization basin could perhaps double as part of the chlorination system. Pumping would be done from 4 p.m. to 8 a.m. only. The pumping rate required would be 26,625 gph (100 000 L/hr). The velocity of this flow in an 8-in. (203-mm) pipe is 2.9 ft/sec (0.88 m/sec).

The friction factor varies with the flow velocity, the diameter, material and condition of the pipe and the viscosity of the reclaimed water, but can be approximated at 0.02. Minor losses, such as those on entrance and exit, are insignificant compared to the frictional losses ($L > 1000\ D$). The frictional head loss calculated using the values above is 72 ft (22 m).

The energy equation can now be used to determine the total head that must be developed by the pumping system (see Figure A8). The pressure at points 1 and 2 in Figure A8 is atmospheric, and the velocities are essentially zero. Therefore, these items can be ignored and the equation reduces to:

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[17]Figures are from Building Construction Cost Data, 38th Annual Edition (Robert Snow Means Co., Inc., 1980).

[18]Innovative and Alternative Technology Assessment Manual, EPA 430/9-78-009 (USEPA Office of Water Program Operations, 1978).

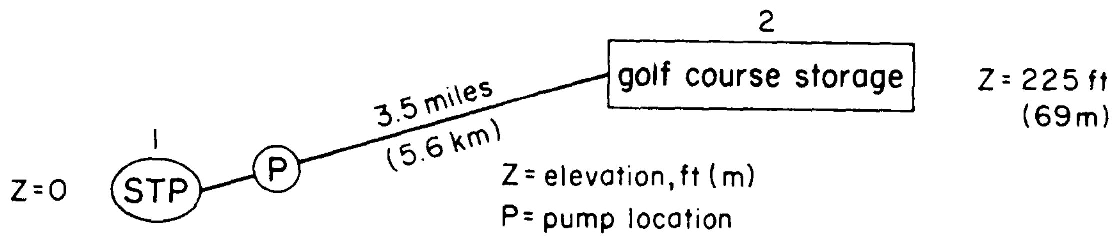

Figure A8. Total head developed by pumping system.

$$h_p = h_L + (Z_2 - Z_1)$$

$$h_p = 297 \text{ ft } (90.5 \text{ m})$$

where h_p is the head that the pump must produce. Assuming pump efficiency is 60 percent, and that the flow is fairly constant, 56 horsepower (HP) is needed. The system would be running 16 hours per day for 93 days a year, and about 2 hours per day for 31 days a year. This is 1550 hours of operation per year. The annual kilowatt-hour requirement would be approximately 65,000. Using wind power to pump this flow is an alternative to consider.

The existing booster pump at the golf course pumps from elevated storage and is not powerful enough to deliver water at the desired pressure and rate from ground-level storage. The golf course superintendent prefers that the pump not be used in the reclaimed water system at any rate, so that he still has the option of switching to potable water if problems with the reclaimed system arise. The extra power that would be needed due to the 100 ft (30.5 m) loss of head to supply reclaimed irrigation water at a maximum rate of 750 gpm (2843 L/mm) is 32 HP.

The total power needed is 72 HP, assuming the existing pump was sized correctly to provide 40 HP. The whole course is watered in 8 hours; the greens only are watered in 1 hour. The total use is 775 hours for the season, and the electrical usage would be 42,000 kWh/yr. Total electrical use of the reclaimed water system would be 107,000 kWh/yr, of which 88,000 kWh/yr would go for the golf course alone. WSMR is currently paying $0.045/kWh; electrical cost at this rate comes to $4815 a year ($3960 a year for the golf course alone).

Current electrical costs to water the course are 2.243 kWh/1000 gal (0.59 kWh/1000 L) for the potable water supply, plus the cost of running the 40-HP booster pump. This is about 76,000 kWh/yr ($3240 per year).

Labor needed for maintenance of the pumps can be extrapolated from Figure 12 to be 53 hours per year for the system at the STP. The cost of maintaining a booster pump at the golf course is already being borne. Capital costs of $35,000 for both pumping systems are from the 1980 Means Guide.[19]

Total Costs

The total costs of the network are summarized in Table A3.

Estimating labor costs at $10 an hour, electricity at 4.5 cents per kilowatt-hour, and chlorine at $200 a ton, total yearly costs are about $35,000. This compares favorably with the $39,000 per year that WSMR is currently paying to water the golf course with potable water. This network was pursued under Stage 3 of the model.

Table A3

Costs of the Reuse Network

	Construction		O&M/Year		
	Total Costs ($)	Total Yearly Costs* ($)	Labor	Materials	Electricity
Pipeline	174,000	17,700	--	--	--
Lined Storage Lagoon	23,500	2,400	--	--	--
Chlorination	35,000	3,600	133 hrs	7 tons (64 MT) Cl_2	5000 kWh
Pumping	35,000	3,600	53 hrs	--	88,000
Total	267,500	27,300	186 hrs	7 tons (64 MT) Cl_2	93,000

*Total yearly costs are calculated assuming a 20-year lifetime at 8 percent interest.

[19] Building Construction Cost Data, 38th Annual Edition (Robert Snow Means Co., Inc., 1980).

Stage 3: Field Test at WSMR

Two wastewater streams at WSMR were sampled on April 7-18, 1980. Three samplers were set up; an automatic flow compositor on the influent to the STP, a 24-hour compositor on the STP effluent, and a 24-hour compositor on the photo lab sump. A flow recorder was put on the STP influent. A voltage recorder was connected to both photo lab sump pumps to determine how often they operated. The photo lab was tested because it is the largest industrial water user on post, and it discharges throughout the evening and late night -- when flow to the STP is otherwise low.

On April 9, 10, 11, 14, 15, samples were collected from 8 a.m. to 8 a.m. the following morning. Flow recorders were left running April 12 and 13, but no samples were taken.

Samples were iced down, preserved with acid, and shipped to AEHA's chemists at Fort Meade. They analyzed for BOD, TOC, metals, hardness, boron, sodium, total Kjeldahl nitrogen (TKN), ammonia (NH_3), nitrite/nitrate, phenols, suspended solids, total dissolved solids (TDS), oil and grease, chloride, phosphate, cyanide, iron, coliforms, pH, and flow rate. The results are presented in Tables A4 through A6 and Figure A9.

Samples were also taken from six monitoring walls close to STP outfall to determine both the groundwater quality in the area and any effect the effluent discharge might have. Soil samples were taken from the golf course greens, fairways, and driving range, and from the ball fields near the course, and shipped back to AEHA for characterization. Permeability tests were done on site with an experimental device called an infiltrometer.

A comparison of the STP effluent quality with the water quality tolerable for irrigation shows that the effluent is entirely suitable, except for its high cyanide concentrations. The STP effluent contained an average cyanide concentration of 0.29 mg/L, which is almost three times the highest standard for irrigation water found in the literature. A cyanide mass balance shows that the photo lab is a significant source of cyanide in the STP influent, but probably not the only one. Complete removal of cyanide only from the photo lab waste stream probably would not result in suitable cyanide concentrations in the STP effluent. Alkaline chlorination is the most common method of removing cyanide; all of the STP effluent will have to be chlorinated to the breakpoint level during the irrigation season.

The flow and water quality data obtained at WSMR were used as inputs to both the yearly and daily cascade computer programs to consider irrigation of the golf course, driving range, and athletic fields with the STP effluent. The costs calculated by the program were considerably higher than the rough costs obtained using Mean's Building Construction Cost Data. The greatest discrepancies occurred in the pipe and pump figures. These differences are to be resolved in future runs.

Table A4

Sewage Treatment Plant Influent

Parameter	Date of Sample Collection -- April 1980					
	9th	10th	11th	15th	16th	Average
pH	7.0	7.3		7.4		NA
Conductivity (mhos)	880	750		810		813
BOD_5 (mg/L)	139	122		162		141
Total organic carbon (mg/L)	85	68		149		101
Phenol (mg/L)	<0.05	<0.05		0.02		<0.04
Cyanide (mg/L)	0.76*	0.34*		0.54		0.55
Total suspended solids (mg/L)	153	78		202		144
Total dissolved solids (mg/L)	472	418		462		451
NO_2NO_3/N (mg/L)	<0.01	0.04		0.02		0.02
NH_3N (mg/L)	21	17		26		21.3
Total Kjeldahl nitrogen (mg/L)	9.3	8.4		12		9.9
Total phosphates (mg/L)	28	23		38		29.7
Fluoride ion (mg/L)	0.42	0.40		0.45		0.42
Chloride ion (mg/L)	46	43		46		45
Oil and grease (mg/L)**		40		35	24	33

*Unpreserved sample -- actual values may have been higher.
**Oil and grease analyses conducted on a grab sample; all other analyses conducted on 24-hour flow -- composited sample.

Table A5

Sewage Treatment Plant Effluent

Parameter	Date of Sample Collection -- April 1980					
	9th	10th	11th	15th	16th	Average
pH	7.4	7.4	7.7	7.5		
Conductivity (mhos)	720	700	740	710	760	726
BOD_5	12	12	6	13	9	10.4
Total organic carbon (mg/L)	29	23	24	22	23	24.2
Phenol (mg/L)	<0.05	<0.05	<0.05	<0.1	<0.1	<0.07
Cyanide (mg/L)	0.32*	0.33*	0.31*	0.22	0.28	0.29
Total suspended solids (mg/L)	14	4	7	7	1	6.6
Total dissolved solids (mg/L)	489	464	466	434	458	462
NO_2NO_3/N (mg/L)	3.3	4.0	4.8	4.9	6.6	4.1
NH_3/N (mg/L)	8.4	6.8	10	9	7.6	8.4
Total Kjeldahl nitrogen (mg/L)	11	8.1	13	9.3	8.4	10.0
Total phosphates (mg/L)	7.5	7.2	7.7	7.6	8.0	7.6
Fluoride ion (mg/L)	0.44	0.55	0.45	0.40	0.51	0.47
Chloride ion (mg/L)	48	44	45	49	51	47.4
Oil and grease (mg/L)**	--	6	--	10	4	6.7

*Unpreserved sample -- actual values may have been higher.

**Oil and grease analyses conducted on a grab sample; all other analyses were performed on 24-hour flow -- composited samples.

Table A6

Photo Lab Data Comparison

	14 April 1030 - 1530	14 April 1730 - 1930	15 April 1200 - 2100	16 April 1145 - 2145	
Processor					
		Runtimes (minutes)			
P-003 (B&W)			31	52	
P-004 (B&W)				90	
P-005 (B&W)			84	76	
P-006 (Color)	95	100	245	100	
P-009 (Color)	30	120	140	275	
P-010 (B&W)			52	42	
Parameters		Concentration (mg/L)			Average*
TOC	340	357	245	283	281
CN	38	12	7.5	11	11.4
NO_2NO_3/N	1.6	1.9	2.9	2.2	2.38
NH_3/N	100	23	22	95	62.5
TPO_4/P	0.68	14	3.6	13	9.16
F	0.54	0.41	0.54	0.84	0.67
Cl	214	39	269	255	235
Hardness/$CaCO_3$	259	24[illegible]	274	238	252
Metals					
Na	212	250	268	525	390
Ba	--	--	--	--	--
Fe	18	5.7	4.1	5.5	5.7
Pb	--	--	--	--	--
As	--	--	--	--	--
Cd	--	--	--	--	--
Hg	0.0002	--	0.0002	--	--
Se	--	--	--	--	--
Ag	2.93	0.58	1.63	3.24	2.39
C	0.44	0.30	0.043	0.73	0.43
Ca	35	35	41	37	38
Mg	34	35	40	33	36
Cr	0.025	0.025	0.025	0.025	0.025

*Flow weighted average based on total flow of 31,430 gal (122,910 L).

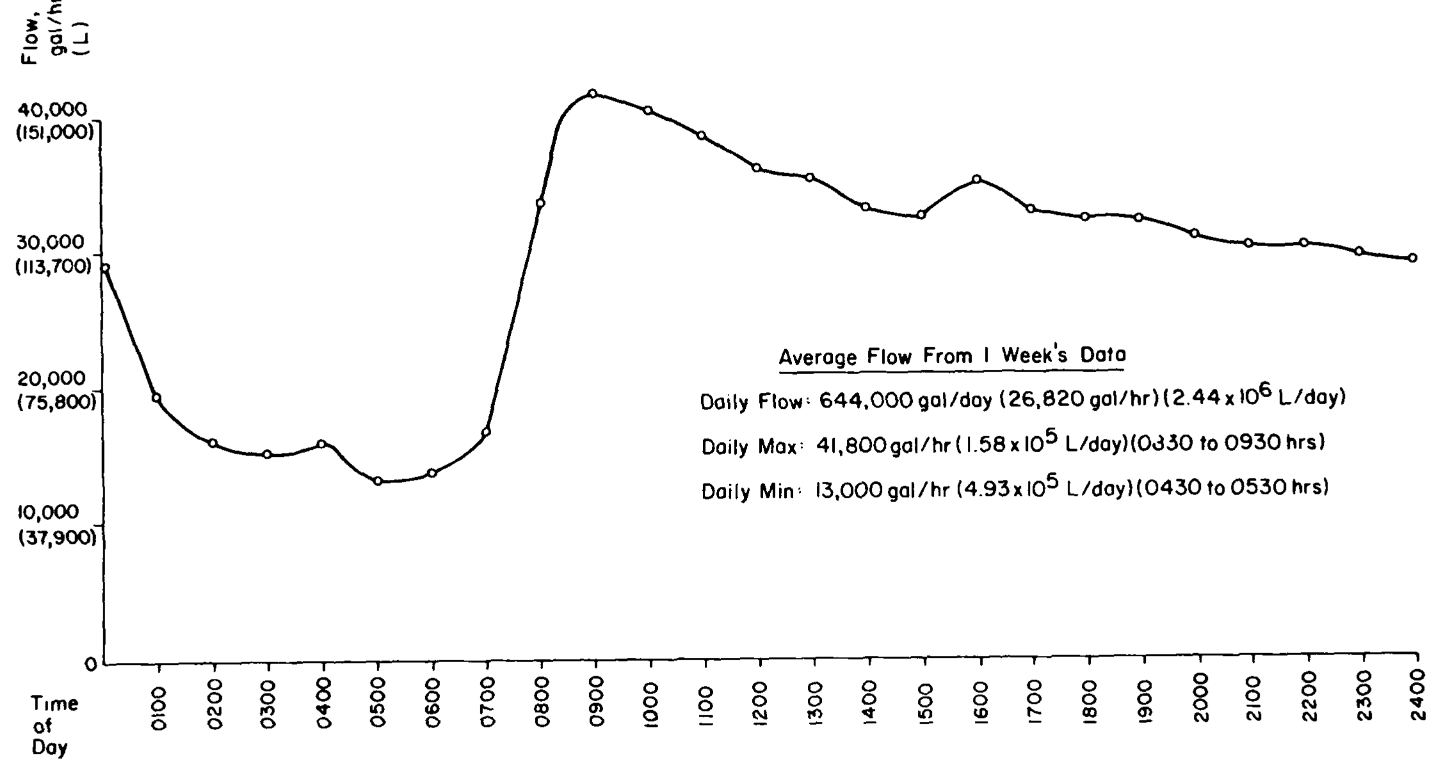

Figure A9. Average flow.

APPENDIX B:

WATER AND EFFLUENT QUALITY

The tables in this appendix provide information on tolerable water quality and typical effluent quality for common Army activities. The references mentioned in the tables are listed on pp 98 through 102.

Table B1

Tolerable Water Supply Quality -- Aircraft Wash Racks

Constituent	Concentration, mg/L SCS Report*
BOD_5	10
COD	25
Phenol	2.0
SS	10
TDS	2000
O&G	5.0
Cl	600
NO_3	NS
NH_4	5.0
PO_4	NS
Na	600
$CaCO_3$	500
B	NS
CN	0.5
Fe	40
MPN (total coliform)	<2.2/100 ml

*Curtis J. Schmidt, Ernest V. Clements, Leanne Hammer, Subpotable Water Reuse at Army Fixed Installations: A Systems Approach, Volume I, ADA075159 (SCS Engineers, supported by U.S. Army Medical Research Development Command, August 1979). All report values are SCS estimates. NS indicates not significant.

Table B2

Typical Effluent Quality -- Aircraft Wash Racks

Constituent	Concentration, mg/L SCS	 Ref. 15*
BOD_5	5700	270
COD	8400	976
Phenol	8.5	
SS	470	164
TDS	SD**	
O&G	280	305
Cl	SD	
NO_3	0.8	1.7
NH_4	(0.1)+	
PO_4	80	1.6
Na	SD	
$CaCO_3$	SD	
B	(0.1)+	
CN	(0.005)+	
Fe	1.1	

*Samples of wastewater from aircraft washing.
**SD indicates dependent on source quality.
+Values in parentheses are SCS estimates, other values in that column are based on Reference 1.

Table B3

Tolerable Water Supply Quality --
Air Pollution Wet Scrubbers

Constituent	Concentration, mg/L SCS Report*	Ref. 2**
BOD_5	100	
COD	200	
Phenol	2.0	
SS	100	14
TDS	2000	900
O&G	50	
Cl	600	100
NO_3	50	22.0
NH_4	20	2.0
PO_4	NS	14.0
Na	600	
$CaCO_3$	300	
B	NS	
CN	0.5	
Fe	20	
Mg	200	

*All values are SCS estimates. NS indicates concentration is not significant.
**Sewage effluent used as make-up to gas-cleaning system.

Table B4

Air Pollution Wet Scrubbers --
Typical Effluent Quality

Constituent	Concentration, mg/L SCS Report*	Ref. 3**	Ref. 4+
BOD	10	180+	
COD	720	350	1-390
Phenol	(0.001)		
SS	3270	150	
TDS	(5000)		2800-92,500
O&G	0.3	150	
Cl	(400)		420-33,000
NO_3	(28)		
NH_4	(0.1)		
PO_4	5.4	250	
Na	(72)		10-29,000
$CaCO_3$	(200)	250	
B	(0.1)		
CN	(.005)		
Fe	5.3		

*Values in parentheses are SCS estimates; other report values are from Reference 1.
**Values are characteristic of phosphate waste waters from fume scrubbers.
+Flue gas desulfurization sludge liquors.

Table B5

Base Housing Water Supply Quality
(Also Included Are Unclassified Office Space, Hospitals, and Commercial Services)

Constituent	Concentration, mg/L SCS Report*
Phenol	0.001
CN	0.2
Cd	0.01
TDS	500
Cl	250
SO_4	250
Cr total	0.05
Cu	1.0
Fe	0.3
Pb	0.05
Mn	0.05
NO_3 as N	10
NH_3	5
As	0.05
Ba	1.0
Hg	0.002
Se	0.01
Ag	0.05
Chlorinated hydrocarbons	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2.4D	0.1
Silvex	0.01

*National Interim Primary Drinking Water Regulations, maximum limit based on Reference 58.

Table B6

Typical Base Housing Sewage
(Also Includes Commercial and Unclassified Office Space)

Constituent	Concentration, mg/L SCS Report*
BOD	200
COD	300
Phenol	0.15
SS	300
TDS	300+
O&G	50-100
Cl	100+
NH_4	30
PO_4	10
Na	50+
$CaCO_3$	80+
B	1.0+
CN	0.01
Fe	1.0+
Alk (as $CaCO_3$)	50-100
Total coliform	$1X10^6$ - $4.6X10^7$/100 ml

*Plus indicates source water concentration.

Table B7

Low Pressure Boilers -- Tolerable Water Supply Quality

Constituent	Concentration, mg/L SCS Report[a]	Ref. 37[b]	Ref. 37[c]	Ref. 44[d]	Ref. 45	Ref 60	Ref. 5[e]
BOD_5	(1.0)						
COD	(3.0)	100		5			
Phenol	(0.1)						
SS	(10)	15,000	10	10		300-600	
TDS	2000	35,000	700	700	500-3000	3000-5000	3000-500
Hardness ($CaCO_3$)	10	5000	350	20	80	0	80
O&G	(0.0)					1.0	
Cl	(200)	19,000					
NO_3	NS						
NH_4	(2.5)		.1				
PO_4	(0.3)					40-80	
H_2S	(0.0)						5
Na	(200)						
CO_3	40				200		200
B	(2.0)						
CN	(0.5)						
Fe	(0.5)	80	1.0	1.0			
Mn	(0.5)	10	.3	.3			
Si as SiO_2	(50)	150	30	30	40	100-133	40
Alk (as $CaCO_3$)	(100)	500	350	140			
pH	79.0		7-10	8-10	8.0	9.5	8.0 min.

(a) Values in parentheses are estimates; others are from Reference 5. NS indicates not significant.
(b) Pp 370, 377.
(c) For steam generation (maximum values); same as Reference 61.
(d) From Federal Water Pollution Control Administration (FWPCA) Water Quality Criteria, 1968.
(e) Appears that Reference 44 was based on Reference 5.

Note: for heat exchangers, need better water quality listed in Reference 61.

Table B8

Low Pressure Boilers -- Typical Effluent Quality

	Concentration, mg/L	
Constituent	SCS Report	Ref. 46**
BOD	5.0	
COD	15.0	
Phenol	0.5	
SS	50	
TDS	3500	
O&G	0.5	
Hardness ($CaCO_3$)	50	10
Cl	1000	
NO_3	150	
NH_4	2.0	
PO_4	60	
Na	1000	
CO_3	200	
B	10	
CN	2.5	
Fe	2.5	1.4
Mn	2.5	
Zn	1.0	0.01
Si	2.5	
Ni	0-.1	0.05
Cu	3.0	0.05
Alk (as $CaCO_3$)	500	
Cr	.005	<.005
pH	10.0	

*Values are five times source water except PO_4, Cu, Cr, Zn, Ni: see Table B7.
**Examples of boiler blowdown.

Table B9

Cooling Water (Recirculating Systems) -- Tolerable Water Supply Quality (Also Dynamometers)

	Concentration, mg/L					
Constituent	SCS Report[a]	Ref. 37[b]	Ref. 40[c]	Ref. 41[d]	Ref. 42	Ref. 43
BOD_5	10		10	5		
COD	75	100	--			75
Turb.	50				2	
SS	100	15,000	10	200-400		100
TDS	500-1500	1000	--	3000	500	
Hardness ($CaCO_3$)	50	850	--	1200		130
Fe	0.5	80	--		0.3	0.5
Mn	0.5	10			0.3	0.5
Si as SiO_2	50	150	10	175	50	
Al	0.1	3				0.1
Ca	50	500	28			50
HCO_3	24	600				
SO_4	200	680	200			200
Cl	500	500	--	2000	200	500
Alk as $CaCO_3$	350	500	--			20
MBAS	1.0	1.3				1.0
Total P	0.3	4.0	.5	.4		

(a) Values are from References 5 and 37.
(b) Values are maximums on p 370. Reported values from Reference 37 are for steam generation purposes; also values same as Reference 61. References 38 and 39 agree with SCS Report values.
(c) Desired quality for Arizona nuclear project based on previous experience with freshwater sources. Dash indicates "not important."
(d) Recommended control limits.

Table B10

Cooling Waters (Once-Through) -- Tolerable Water Quality
(Also Dynamometers)

	Concentration, mg/L			
Constituent	SCS Report*	Ref. 37**	Ref. 37+	Ref. 61
SS	100	5000	5000	5000
Total P	1.0	4		4
Hardness ($CaCO_3$)	650	850	850	850
Fe	0.5	14		14
Mn	0.5	2.5		2.5

*Values are SCS estimates; other constituents are not critical.
**Maximum values, p 370.
+P 377, steam generation plants using freshwater.

Table B11

Typical Effluent Quality -- Cooling Tower Blowdown (Also Dynamometers)

		Concentration, mg/L				
Constituent	SCS Report[a]	Ref. 32[b]	Ref. 33[c]	Ref. 34[d]	Ref. 35	Ref. 36
Alkalinity ($CaCO_3$)	SD					
BOD_5	7.0					
COD	35					
Phenol	0-0.1					
SS	30					
TDS	SD		2680		856	4910
Cl	SD		631	135.3	32	130
P(total)	2.1	23.9		91.5	1.4	
Hardness ($CaCO_3$)	SD					
Fe	0.6			7.8	0.74	
SO_4	SD	340	758	1200	386	3200
Ca	0-2.0				0.23	
Cr	0.05				5.7	
Mn	0.1				0.12	
Zn	3.0	1.63		2.08	2.2	
Ni	1.0				0.005	
pH	7.4		6.85			

(a) Used References 6 and 7. SD -- indicates dependent of source quality, number of cycles and blowdown volume, typically five times source.
(b) Blowdown of cooling tower -- simulated blowdown.
(c) Cooling tower blowdown.
(d) Blowdown characteristics, mean concentration.
(e) Median concentration of blowdown in power plants.

Table B12

Fire Protection/Spill Washdown Reservoirs -- Tolerable Water Supply Quality

Constituent	Concentration, mg/L SCS Report*	Ref. 59**
BOD	10	85 percent reduction
COD	22	
Phenol	0.01	
SS	10	95 percent reduction
TDS	NS	
O&G	1.0	
Cl	NS	
NO_3	5.0	
NH_4	10	
PO_4	1	
Na	NS	
$CaCO_3$	NS	
B	0.1	
CN	0.1	
Fe	5.0	
pH	5.0-9.0	

*NS indicates not significant. All values are estimates by SCS.
**Should also be stable and disinfected, treatment plant effluent.

Table B13

Hospitals -- Typical Effluent Quality

Constituent	Concentration, mg/L SCS Report*	Ref. 23**
BOD	250	135
COD	850	
SS	200	190
TDS	1400	1200
O&G	45	
PO_4 as P	170	
SO_4	35	
Turb. JTU	50	98
Alk ($CaCO_3$)	125	
ABS	75	
Cd	0.02	
Ca	15	
Cr	1.1	
Fe	0.3	
Pb	0.3	
Mg	16	
K	34	
Na	360	
Ag	0.3	
pH	7.6	

*Values are from Reference 6.
**Values are for Army mobile hospital "Must" waste.

Table B14

Irrigation -- Tolerable Water Supply Quality

Constituent	SCS Report[a]	Ref. 47[b]	Ref. 48[c]	Ref. 49[d]	Ref. 50[e]	Ref. 51[f]	Ref. 52[g]	Ref. 53[h]
	Concentration, mg/L							
BOD	30	76-204	12		D	2^{o}Eff.	<30	
COD	60	140-509	24		I			
Phenol	0.5	-			S			
SS	50	54-450	19		I			
TDS	2000	765-1053	654	468	F	<2000		2000
O&G	30	-	13		E			
Cl	350	212-319	85	118	C			
NO_3	10	6-2.5	1.86	19	T			
NH_4	20	16.5-55	3.19	13.2	O			
PO_4	NS	.7-6.9	2.75	19	N			
Na	350	185-300	64		90	F 2^{o}		
$CaCO_3$	NS	-			O			
					L T			
B	3.0	-		0.53	L R			
				O E				
				W A				
CN	.01	-			I T			
F	10	trace	0.4		O E			
pH	4.5-9.0	7.8-8.1		G E				
Coliform		-	700		T			
Agriculture	2.2/100 ml			T				
Landscape 23/100 ml						<500 ml	<1000	<1000

(a) All values are SCS estimates. NS -- indicates constituent not significant.
(b) Used 1^{o} effluent, no health problems, farm in Hungary.
(c) Values of applied effluent in United States.
(d) 2^{o} effluent used for irrigation.
(e) Thirty-seven states in United States require 2^{o} treatment and disinfection for landscape irrigation.
(f) Arizona state regulations.
(g) Australian reuse for landscape irrigation.
(h) For golf course irrigation.

Table B15

Laundries -- Tolerable Water Quality

Constituent	SCS Report*	Ref. 22+	Ref. 5
	Concentration, mg/L		
BOD	45		
COD	500		
Phenol	0.05		
O+G	10		
SS	30		
TDS	3300	<1500	
NH_3-N	1.5		
Hardness ($CaCO_3$)	50		50
Alk ($CaCO_3$)	60		60
Fe	1.0		1.0
Mn	1.0		0.2
Zn	0.5		
Cr	0.5		
Cu	(1.0)**		
CN	(0.2)**		
As	(0.5)**		
Pb	.5		
MPN	(2.2/100 ml)**	10	
pH	6.0-6.8	5-7.5	6.0-6.8

*Used References 5, 19, 23, 16.
**Values in parentheses estimated by SCS.
+Numbers are for tentative National Aeronautics and Space Administration (NASA) standards.

Table B16

Industrial Laundries -- Typical Effluent Quality

Constituent	Concentration, mg/L						
	SCS Report[a]	Ref. 22[b]	Ref. 23[c]	Ref. 23A[d]	Ref. 13[e]	Ref. 31	Ref. 63[f]
BOD_5	450	435	4930	256	370-635	152	1600
COD	2000	1853	20,200	3820			2700
SS	1000	167	4020	290	210-540	116	250-500
TDS	2000	3912	8013	3268	800-2100		
O+G	300	211	3900	341	170-550		
Alk ($CaCO_3$)	500	848			-511		
Fe	1.0	0.75				0.71	
Si	130	310					
Ca	740	23					
Mg	6.4	1.5					
Cu	0.3	0.43	3.0			0.16	
Pb	0.7	0.32	20.0			0.16	
Cd	0.04	0.03	0.4				
Zn	0.5	0.14	10.			0.406	
Cr	0.06	0.09	2.0			0.10	
Ni	2.1	0.11				0.05	
Hg	0.001-0.007	0.001				0.00013	
pH	11.2	11.2	-	11.1	9.0-10.3	10.3	8-9

(a) Values from References 6, 7, 19, 20 16, 21.
(b) Dirty sample at a commercial laundry.
(c),(d) Two industrial laundries.
(e) Studies based on V. L. Snoyink ct al., USAF Mobility Program Wastewater Treatment System, Technical Report AFWL-TR-71-169 (Air Force Weapons Laboratory, April 1972).
(f) P 446, uses as source H. E. Painter, in Water and Water Pollution Handbook, L. E. Ciaccio, ed., Vol I (Marcel Dekker, 1971), p 350.

Table B17

Laundromat -- Effluent Quality

Constituent	SCS Report*	Ref. 17**	Ref. 18	Ref. 30
	Concentration, mg/L			
BOD_5	200		243	118-284
COD	400	447	572	562-662
SS	130	173		100-127
TDS	360	812	1270	975-1140-275
O&G	750			
PO_4	220	148	267	140-275
NH_3-N	3.0	3.0		
NO_3	1.0	4.0		
$CaCO_3$	250			
ABS	60	44	63	39-80
Turbidity	250			
pH	8.2	-		6.9-7.0
Alkalinity	182	182		

*References are 6 and 16.
**Average values for typical launderette waste.

Table B18

Metal Cleaning -- Typical Effluent Quality

Constituent	SCS Report*	Ref. 26**	Ref. 27+
	Concentration, mg/L		
COD	3000	1,167,500	10,100
SS	300	1210	550
O+G	350	962	1050
Phenol	70	3.24	3000
PO_4	40	2.0	
CN	0.6		
Pb	0.4	0.26	
Zn	6.0	1.5	
Cr	25	31.3	100
Cd	0.5	0.2	
pH	9.0		8.3
Alk ($CaCO_3$)	400		
MBAS	3.0		

*Values from References 24 and 25.
**Analysis of paint stripping waste from holding pit. Average values.
+Characteristics of phenolic paint stripping wastewater.

Table B19

Metal Electroplating and Finishing Rinse Waters --
Tolerable Water Supply Quality, Also Metal Cleaning

	Concentration, mg/L
Constituent	SCS Report*
BOD	1.0
COD	3.0
TDS	500
SS	1.0
Phenol	0.001
Hardness ($CaCO_3$)	10
As	0.05
B	1.0
Cd	0.01
Cr	0.05
Cu	1.0
CN	0.2
Fe	0.3
Mn	0.05
NH_4	0.5
NO_3	10
Pb	0.05
SO_4	5.0
HCO_3	5.0
Zn	5.0

*All values estimated by SCS.

Table B20

Paint Booth Water Walls --
Tolerable Water Supply Quality

	Concentration, mg/L
Constituent	SCS Report*
BOD_5	30
COD	60
Phenol	NS
SS	60
TDS	NS
O+G	30
Cl	NS
NO_3	NS
NH_4	15
PO_4	NS
Na	NS
$CaCO_3$	NS
B	NS
CN	0.5
Fe	NS

*NS indicates concentration not significant;
all values are estimates by SCS.

Table B21

Paint Booth Water Walls -- Typical Effluent Quality

Constituent	Concentration, mg/L SCS Report*
BOD_5	8100
COD	13,600
Phenol	1.2
SS	2800
TDS	SD
O+G	280
Cl^-	SD
NO_3	(28)
NH_4	(0.1)
PO_4	(3.0)
Na	SD
$CaCO_3$	SD
B	(0.1)
CN	(.005)
Fe	3.2
Cr (total)	13
Cu	(0.005)
MBAS	4900

*Values in parentheses are estimates by SCS, other values from Reference 1. SD indicates source-dependent.

Table B22

Photographic Laboratories -- Tolerable Water Supply Quality

Constituent	Concentration, mg/L SCS Report*	Ref. 5**	Ref. 62+
BOD	0.1		
COD	1.0		
Phenol	0.001		
SS	1.0		
TDS	700		<200
O+G	0.2		
Cl^-	200	<25	
NO_3	20		
NH_4	0.1		
PO_4	3.0		
Na	100		
$CaCO_3$	400	100	100
B	0.1		
CN	0.01		
Fe	0.3	<0.1	0.02 together
Mn	0.5		
Cu	0.5	.5	

*Values are estimates by SCS.
**Fe >0.1 may cause staining; need good water for mixing developers of Cl^- <25 mg, although salt water can be used for washing.
+Used for source: Report of the U.S. Study Commission-Texas (March 1962), p 299.

Table B23

Photographic Laboratories --
Typical Effluent Quality

Constituent	Concentration, mg/L SCS Report*	Ref. 8**	Ref. 9+
BOD_5	300	225	
COD	500	752	500
Phenol	(0.001)		
SS	225		150
TDS	2900		2000-4000
O+G	(4.0)		
Cl^-	SD		250
NO_3	(8.8)		
NH_4	(16)		
PO_4	(9.3)		
Na	SD		750
$CaCO_3$	SD		
B	18		
CN	(4.8)	0.57	5.0
Fe	2.0		5.0
Ag	.5	0.45	
pH	7.8		7.5-8.3

*Values in parentheses are estimates from SCS; other values in SCS Report are from 6 and 7. SD indicates dependent on source water quality.

**Only items of concern.

+Also has values for additional characteristics, such as SO_4^-, SO_2^-, alkalinity, hardness, Si, HCO_3^-, MG, turbidity.

Table B24

Recreational Lakes (Limited Body Contact) -- Tolerable Water Supply Quality

	Concentration, mg/L						
Constituent	SCS Report(a)	Ref. 45(b)	Ref. 56(c)	Ref. 5(d)	Ref. 37(e)	Ref 57(f)	Ref. 62(g)
BOD	10						
COD	60						
Phenol	(0.01)				0.1		
SS	10				25		
TDS	(2000)*	3000					
O+G	(5.0)						
Cl	300						
NO_3	2.5						
NH_4	0.1			1.5	0.02		
PO_4	0.3				0.2		
Na	250						
$CaCO_3$	NS						
B	0.1						
CN	(0.1)		0.05		0.005		
Fe	(5.0)						
pH	5.0-9.0			6.7-8.6	5.0-9.0		6.0-8.5
MPN	<2.2/100 ml	240-2400		<2000 avg.	1000/100 ml	1000 Swim 1000-10,000 fish	50-100
Temp. (max.)	86°F				93°F.		

(a) NS indicates not significant, values in parentheses are SCS estimates.
(b) Values tolerated by most freshwater fish.
(c) Toxic to some fish.
(d) Recreational lakes.
(e) For freshwater fish.
(f) Values varied between states.
(g) Bathing, fish life, p 254.

Table B25

Steam Cleaning -- Typical Effluent Quality

Constituent	Concentration, mg/L SCS Report*
BOD	1300
COD	2800
Phenol	3.0
SS	1000
TDS	-
O+G	245
Cl^-	-
NO_3	30
NH_4	0.1
PO_4	65
Na	70
$CaCO_3$	-
B	0.1
CN	<0.01
Fe	3.6
Cd	0.5
Cr^{+6}	0.3
Cu	0.2
Pb	0.6
Ni	<0.05
Zn	2.0
pH	9.7

*Values from Reference 54.

Table B26

Vehicle Wash Racks -- Tolerable Water Supply Quality Using Sewage Treatment Plant Effluent

Constituent	Concentration, mg/L SCS Report*
BOD	10
COD	25
Phenol	2.0
SS	10
TDS	2000
O+G	5.0
Cl^-	600
NO_3	NS
NH_4	5.0
PO_4	NS
Na	600
$CaCO_3$	500
B	NS
CN	0.5
Fe	40
Pb	1.0
Median Coliform #	<2.2/100 ml

*All values estimates by SCS.

Table B27

Vehicle Wash Racks -- Tolerable Water Supply Quality Using Internally Recycled Water

Constituent	Concentration, mg/L SCS Report**
BOD_5	20
COD	100
Phenol	3.0
SS	60
TDS	2000
O+G	5.0
Cl^-	600
NO_3	NS
NH_4	15
PO_4	NS
Na	600
$CaCO_3$	500
B	NS
CN	0.5
Fe	40

*All values are SCS estimates; values labeled NS are not significant.

Table B28

Vehicle Wash Racks -- Typical Effluent Quality

Constituent	SCS Report[(a)]	Ref. 11[(b)]	Ref. 12[(c)]	Ref. 13[(d)]	Ref. 14[(e)]	Ref. 28[(f)]	Ref. 29[(g)]
	Concentration, mg/L						
BOD	60			135-300		80	272
COD	900	336		420-916	64-3400		
Phenol	(0.01)			0.02-6.7			
SS	2000	2864		27-60		310	
TDS	SD	175		500-580	570-12,900		500
O+G	60	14.7	100	4-50	19-1050	225	333
Alk ($CaCO_3$)	115	131					
Cl^-	SD						
NO_3	(3.3)			1-7			
NH_4	(0.01)						
P (total)	33						
PO_4	(12)		15	18-105	2-580		
Na	SD		150				
$CaCO_3$	SD						
B	(0.01)						
CN	(0.005)						
Fe	4.7	31.3	1	0.1-0.7			
Zn	2.9		1	0.1-0.8			
Pb	2.5		1	0.1-0.2			
Mg	15						
Ca	31						
LAS			1		0-530		

(a) Values in parentheses are SCS estimates; other values from References 10 and 6, SD: dependent on source water.
(b) Values from rough wash facility, dirt removal from water impact forces only.
(c) Values are for dilute synthetic waste, based on composite samples.
(d) Washrack waste water.
(e) For a particular wash site, values were either all high or all low.
(f) Waste water design average.
(g) Effluent from maintenance area.

Table B29

Summary of Tolerable Water Supply Quality and Typical Effluent Wastewater Quality

Activities	Turb.	BOD_5	COD	Phenol	SS	TDS	O&G	Cl^{-1}	NO_3	NH_4	PO_4	Na	$CaCO_3$	B	CN	Fe	MPN* (Total Coli.)	Mg*
1. Aircraft wash racks																		
TWQ	X	10	25	2	10	2000	5	600	NS	5	NS	600	500	NS	0.5	40	<2.2	
TEWQ	X	2985	4688	8.5	317	SD	293	SD	1.3	0.1	41	SD	SD	0.1	0.005	1.1		
2. Air pollution wet scrubbers																		
TWQ	X	100	200	2.0	100	2000	50	600	50	20	NS	600	300	NS	0.5	20		200
TEWQ	X	95	720	0.001	3270	26,000	75	5000	28	0.1	128	4870	225	0.1	0.005	5.3		
3. Base housing, hospital and commercial services																		
TWQ	X			0.001		500		250	10						0.2	0.3	2.35×10^7	
TEWQ	X	200	300	0.15	300	300	75	100		30	10	50	80	1.0	0.01	1.0		
4. Low pressure boilers																		
TWQ	X	10	36	0.1	120	200	0.5	200	NS	2.5	30	200		2.0	0.5	0.8		
TEWQ	X	5	15	0.5	50	3500	0.5	1000	150	2.0	60	1000		10	2.5	2.5		
5. Cooling water with recirculating																		
TWQ	50	10	75			128		740								0.5		
Once-through type																		
TWQ	X				3780											9.5		
6. Cooling tower blowdown																		
TEWQ	x	7	35	0.05	30	SD		SD			91					0.7		
7. Fire protection																		
TWQ		10	20	0.01	10	NS	1.0	NS	5.0	10.0	1.0	NS	NS	0.1	0.1	5.0		
8. Hospital																		
TEWQ	75	250	850		200	1400	45				170		360			0.3		16
9. Irrigation																		
TWQ	X	30	60	0.5	50	2000	30	350	15	20	NS	350	NS	3.0	0.01	10.0	70	

TWQ - Tolerable water quality
NS = Not significant
TEWQ = Typical effluent water quality
SD = Source dependent
*Per 100 ml

Table B29 (cont'd)

Activities	Turb.	BOD_5	COD	Phenol	SS	TDS	O&G	Cl^{-1}	NO_3	NH_4	PO_4	Na	$CaCO_3$	B	CN	Fe	MPN* (Total Coli.)	Mg*
10. Laundries																		
TWQ	X	45	500	0.05	30	3300		10			1.5					0.2	1.0	6
TEWQ	X	560	2590			1.00		2660	300								1.0	
11. Laundromat																		
TEWQ	250	215	473		139	910		750		3.0	3.0	220		250				
12. Metal cleaning																		
TEWQ			6550	70	425			790				40				0.6		
13. Electroplating																		
TWQ		1.0	3.0	0.001	1.0	500				10	0.5				1.0	0.2	0.3	
14. Paint booth water walls																		
TWQ		30	60	NS	60	NS		30	NS	NS	15.0	NS	NS	NS	NS	0.5	NS	
TEWQ		8100	13,600	1.0	2800	SD		280	SD	28	0.1	3.0	SD	SD	0.1	0.005		
15. Photographic lab.																		
TWQ	X	0.1	1.0	0.001	1.0	700		0.2	200	20	0.1	3.0	100	400	0.1	0.01	0.3	
TEWQ	X	300	584	0.001	225	2900		4.0	SD	8.8	16	9.3	SD	SD	18	4.8	3.5	
16. Recreational Lakes																		
TWQ	X	10	60	0.10	25	2500		5.0	300	2.5	0.1	0.3	250	NS	0.1	0.1	5.0	1000
17. Steam cleaning																		
TEWQ	X	1300	2800	8.0	1000			245		30	0.1	65	70		0.1	0.01	3.6	
18. Vehicle wash racks using sewage treatment plant effluent																		
TWQ	X	10	25	2.0	10	2000		5.0	600	NS	5.0	NS	600	500	NS	0.5	40	2.2
19. Vehicle wash racks using internally recycled water																		
TWQ	X	20	100	3.0	60	2000		5.0	600	NS	15.0	NS	600	500	NS	0.5	40	
20. Vehicle wash racks																		
TEWQ	X	158	900	1.7	2000	SD		127	SD	3.3	0.01	30	SD	SD	0.01	0.005	4.7	

TWQ : Tolerable water quality
NS = Not significant

TEWQ = Typical effluent water quality
SD = Source dependent

*Per 100 ml

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A PROCEDURE FOR EVALUATING SUBPOTABLE WATER REUSE POTENTIAL AT --ETC(U)
NOV 81 J T BANDY, M MESSENGER, E D SMITH
UNCLASSIFIED CERL-TR-N-109 NL

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Table B29 (cont'd)

Activities	Turb.	BOD_5	COD	Phenol	SS	TDS	O&G	Cl^{-1}	NO_3	NH_4	PO_4	Na	$CaCO_3$	B	CN	Fe	MPN* (Total Coli.)	Mg*
10. Laundries																		
TWQ	X	45	500	0.05	30	3300	10				1.5					0.2	1.0	6
TEWQ	X	560	2590			1.00	2660	300									1.0	
11. Laundromat																		
TEWQ	250	215	473		139	910	750			3.0	3.0	220		250				
12. Metal cleaning																		
TEWQ			6550	70	425		790					40				0.6		
13. Electroplating																		
TWQ		1.0	3.0	0.001	1.0	500				10	0.5				1.0	0.2	0.3	
14. Paint booth water walls																		
TWQ		30	60	NS	60	NS	30	NS		NS	15.0	NS	NS	NS	NS	0.5	NS	
TEWQ		8100	13,600	1.0	2800	SD	280	SD		28	0.1	3.0	SD	SD	0.1	0.005		
15. Photographic lab.																		
TWQ	X	0.1	1.0	0.001	1.0	700	0.2	200		20	0.1	3.0	100	400	0.1	0.01	0.3	
TEWQ	X	300	584	0.001	225	2900	4.0	SD		8.8	16	9.3	SD	SD	18	4.8	3.5	
16. Recreational Lakes																		
TWQ	X	10	60	0.10	25	2500	5.0	300		2.5	0.1	0.3	250	NS	0.1	0.1	5.0	1000
17. Steam cleaning																		
TEWQ	X	1300	2800	8.0	1000		245			30	0.1	65	70		0.1	0.01	3.6	
18. Vehicle wash racks using sewage treatment plant effluent																		
TWQ	X	10	25	2.0	10	2000	5.0	600		NS	5.0	NS	600	500	NS	0.5	40	2.2
19. Vehicle wash racks using internally recycled water																		
TWQ	X	20	100	3.0	60	2000	5.0	600		NS	15.0	NS	600	500	NS	0.5	40	
20. Vehicle wash racks																		
TEWQ	X	158	900	1.7	2000	SD	127	SD		3.3	0.01	30	SD	SD	0.01	0.005	4.7	

TWQ - Tolerable water quality
NS = Not significant
TEWQ = Typical effluent water quality
SD = Source dependent
*Per 100 ml

Table B29 (cont'd)

Activities	Cd	SO_4	Cr	Cu	Pb	Zn	As	Ba	Hg	Se	Ag	Alk	Hard-ness	CO_3^{-2}	Mn	Si	pH	Ni
1. Aircraft wash racks																		
TWQ																		
TEWQ																		
2. Air pollution wet scrubbers																		
TWQ																		
TEWQ																		
3. Base housing, hospital and commercial services																		
TWQ	0.01	250	0.05	1	0.05	5	0.05	1	$2x\ 10^{-2}$	0.1	0.05							
TEWQ												75						
4. Low pressure boilers																		
TWQ												200	90	147	0.5	50	8.7	
TEWQ			$5x\ 10^{-3}$	3		1						500	50	200	2.5	2.5	10	0.05
5. Cooling water with recirculating																		
TWQ		320										350	340		0.5	90		
Once-through type																		
TWQ													800		1.8			
6. Cooling tower blowdown																		
TEWQ		SD	0.05			3						SD	SD		0.1		7.4	1.0
7. Fire protection																		
TWQ																	5-1	
8. Hospital																		
TEWQ	0.02	35	1.1		0.3						0.3	125					7.6	
9. Irrigation																		
TWQ																		

TWQ = Tolerable water quality
NS = Not significant
TEWQ = Typical effluent water quality
SD = Source dependent
* Per 100 ml

Table B29 (cont'd)

Activities		Cd	SO_4	Cr	Cu	Pb	Zn	As	Ba	Hg	Se	Ag	Alk	Hard-ness	CO_3^{-2}	Mn	Si	pH	Ni
10. Laundries																			
	TWQ			0.5	1.0	0.5	0.5	0.5					60	50		1.0		5.0-7.5	
	TEWQ	0.04		0.08	0.3	0.7	0.5			4×10^{-3}			500				220	9-11	2.1
11. Laundromat																			
	TEWQ												182					8.2	
12. Metal cleaning																			
	TEWQ	0.5		28		0.4	1.0						400					9.0	
13. Electroplating																			
	TWQ	0.01	5.0	0.05	1.0	0.05	5.0	5×10^{-2}						10		0.05			
14. Paint booth water walls																			
	TWQ																		
	TEWQ																		
15. Photographic lab.																			
	TWQ				0.5											0.5		7.5-8.3	
	TEWQ											0.5							
16. Recreational lakes																			
	TWQ																	5-9	
17. Steam cleaning																			
	TEWQ	0.5		0.3	0.2	0.6	2.0											9.7	0.05
18. Vehicle wash racks using sewage treatment plant effluent																			
	TWQ					1.0													
19. Vehicle wash racks using internally recycled water																			
	TWQ																		
20. Vehicle wash racks																			
	TEWQ	15				2.5	2.9						123						

TWQ = Tolerable water quality TEWQ = Typical effluent water quality * Per 100 ml
NS = Not significant SD = Source dependent

Table B30

Final Lagoon Effluent Quality At Lake City Ammunition Plant and Its Possible Uses

		Possible Use											
Constituent	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
pH	8.5		8.7 Y			5-9 Y	4.5-9 Y	5-7.5 Y					
Total suspended solids	9	100 Y	120 Y	128 Y	3780 Y	10 Y	50 Y	30 Y	1.0 N	60 Y	1.0 N	10 Y	10 Y
Total solids	970	2000 Y	2000 Y	1312 Y		NS Y	2000 Y	3300 Y	500 N	NS Y	700 N	2500 Y	2000 Y
COD	63	200 Y	36 N	75 Y		22 N	60 N	500 Y	3.0 N	60 N	1.0 N	60 N	25 N
TOC	23												
Oil & grease	29	50 Y	0.5 N			1.0 N	30 Y	10 N		30 Y	0.2 N	5.0 N	5.0 N
Sulfate	279			320 Y					5.0 N				
Iron	0.74	20 Y	08. Y	0.5 N	9.5 Y	5.0 Y	10 Y	10 Y	0.3 N	NS Y	0.3 N	50 Y	40 Y
Aluminum	<0.1												
Copper	0.262						1.0 Y		1.0 Y		0.5 Y		
Lead	<0.1						0.5 Y		0.05 N				1.0 Y
Zinc	0.29						0.5 Y		5.0 Y				
Antimony	0.226												
Chromium	<0.025						0.5 Y		0.05 Y				
Mercury	0.0011												

Note: All values are in mg/l except pH

Y = yes, N = No } Answers whether effluent is permissible to use for that purpose

NS = Not significant
(a) = Final lagoon effluent (median value)
(b) = Air pollution wet scrubber
(c) = Low pressure boilers
(d) = Cooling water recirculating
(e) = Cooling water once-through
(f) = Fire protection
(g) = Irrigation
(h) = Laundries
(i) = Plating rinsewater metal cleaning
(j) = Paint booth water wells

Note: (k) = Photographic laboratories
(l) = Recreational lakes
(m) = Vehicle washracks

REFERENCES FOR TABLES B1 THROUGH B30

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